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END CAP TOOLING

R. CUBIZOLLES
N. BAZIN – S. BOUAZIZ

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Summary

- ❑ Overview of the preliminary Tooling based on ESS experience
- ❑ Interfaces with the Hβ cryomodule
- ❑ Mechanical simulations
- ❑ Conclusion

EXPERIENCE FROM ESS

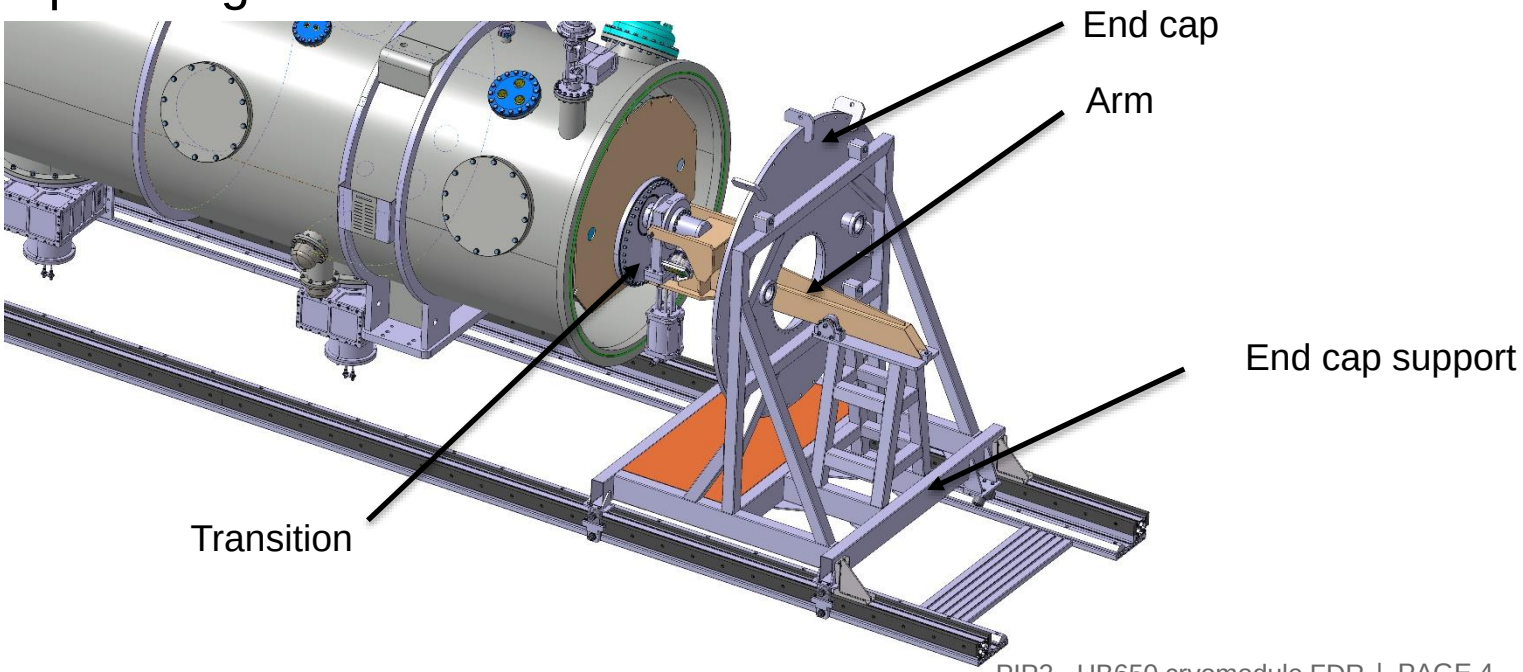
Description of the ESS tooling

The tooling is made of two main parts :

- The end cap support
- The arm

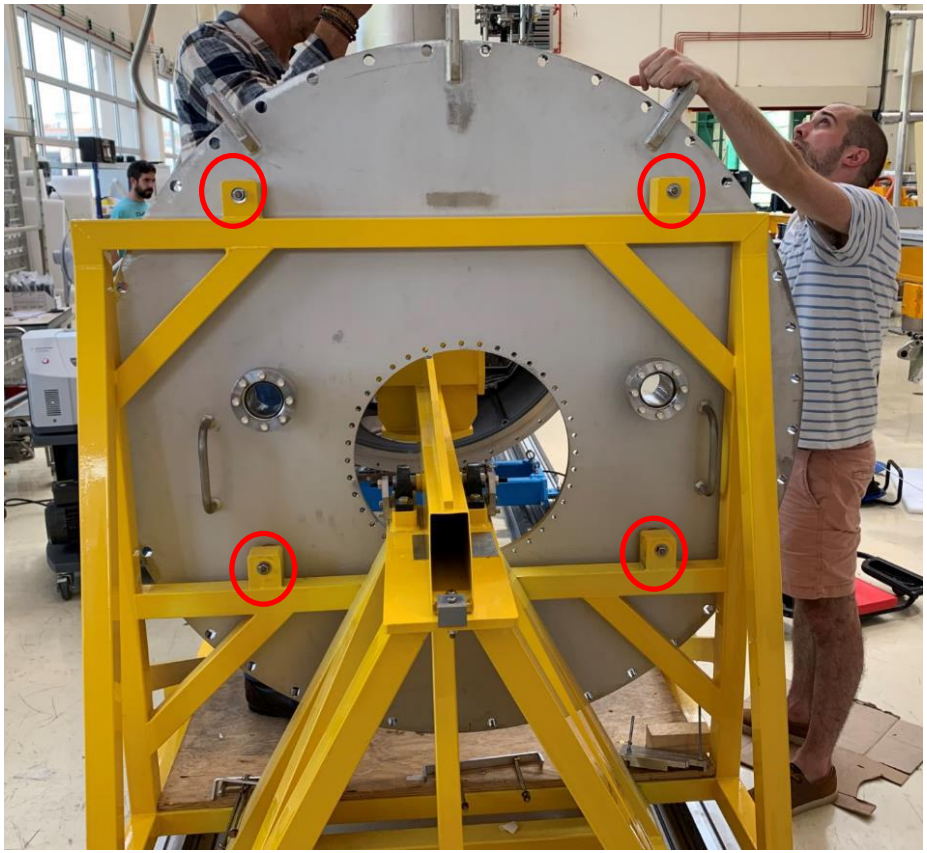
The end cap support and the arm respectively sustain the end cap weight and the transition weight during the closure of the cryomodule.

Rails are used for the assembly of the ESS cryomodule and thus, for the ESS end cap tooling.



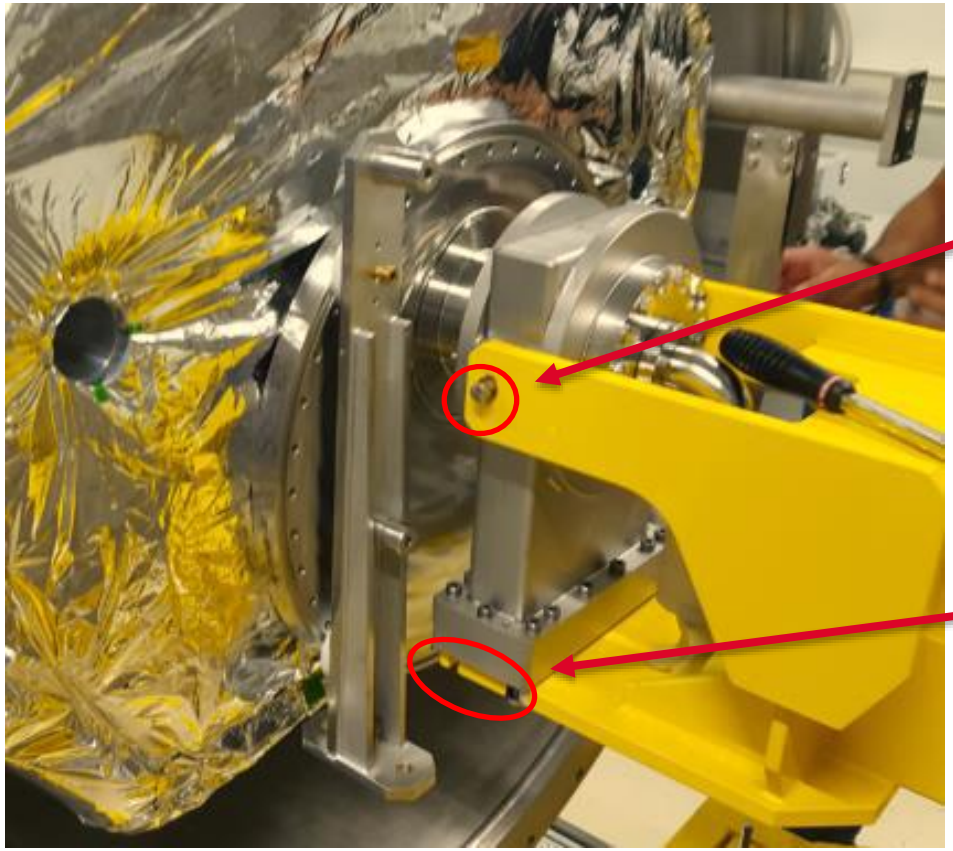
First step of the assembly

- The end cap is fixed to the support in four point by using specific bronze studs.



Second step of the assembly

- The position of the arm is adjusted to the position of the valve. Then, the valve is fixed to the arm with screws that fit in holes in the valve.
- When the transition valve is supported, the cold-warm transition tooling (that maintained the transition during assembly) can be removed.



Upper screws are used in order to avoid a displacement along the beam axis.

Lower screws are just put in contact with the transition.
Thus, no adjustment are done in order to avoid a twist of the bellows.

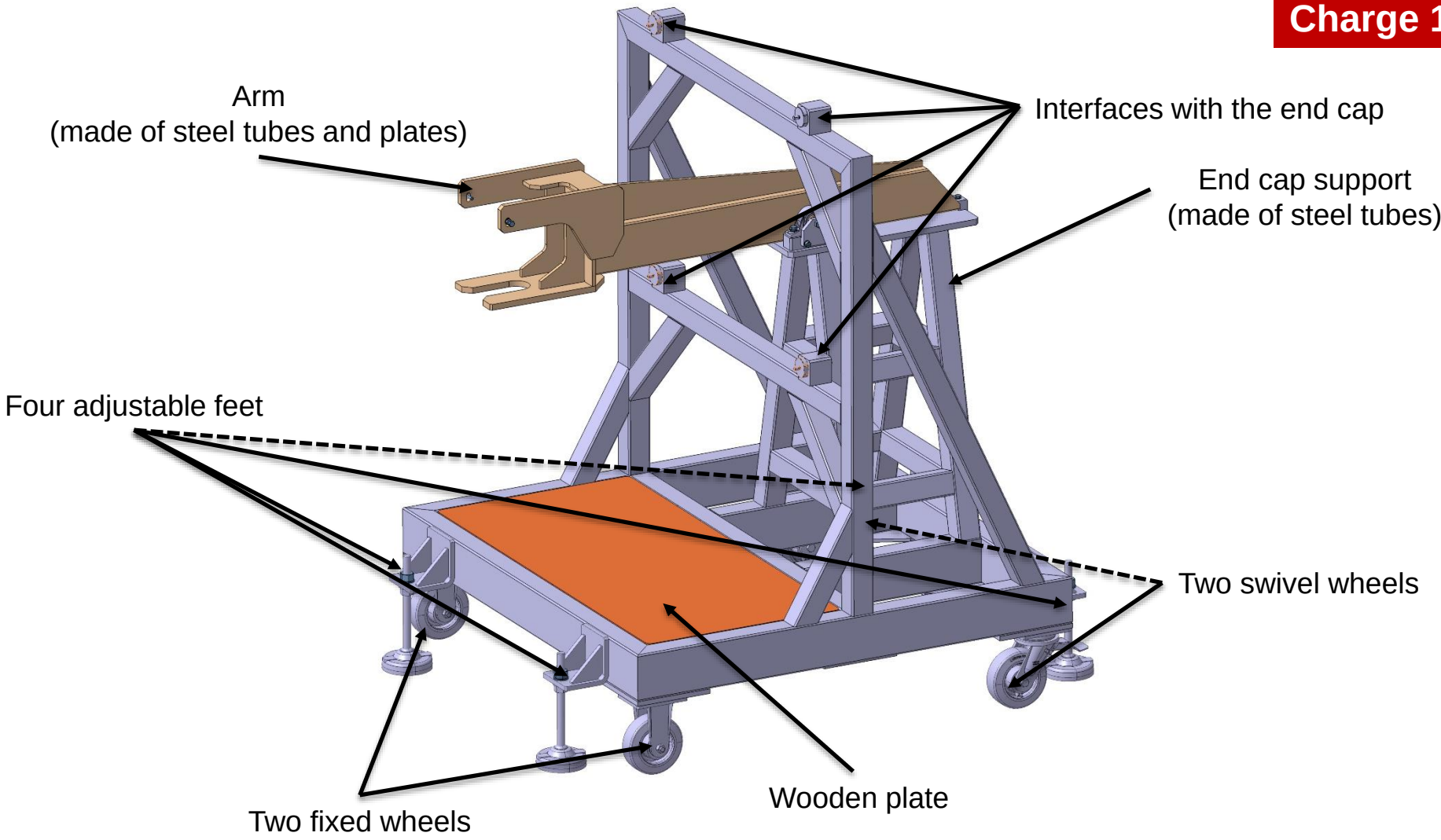
Third and last step of the assembly

- The crane is used to close the door

→ Adjustment of the end cap tilts and positioning can be done properly.

Preliminary design of the tooling for PIP2 end cap assembly

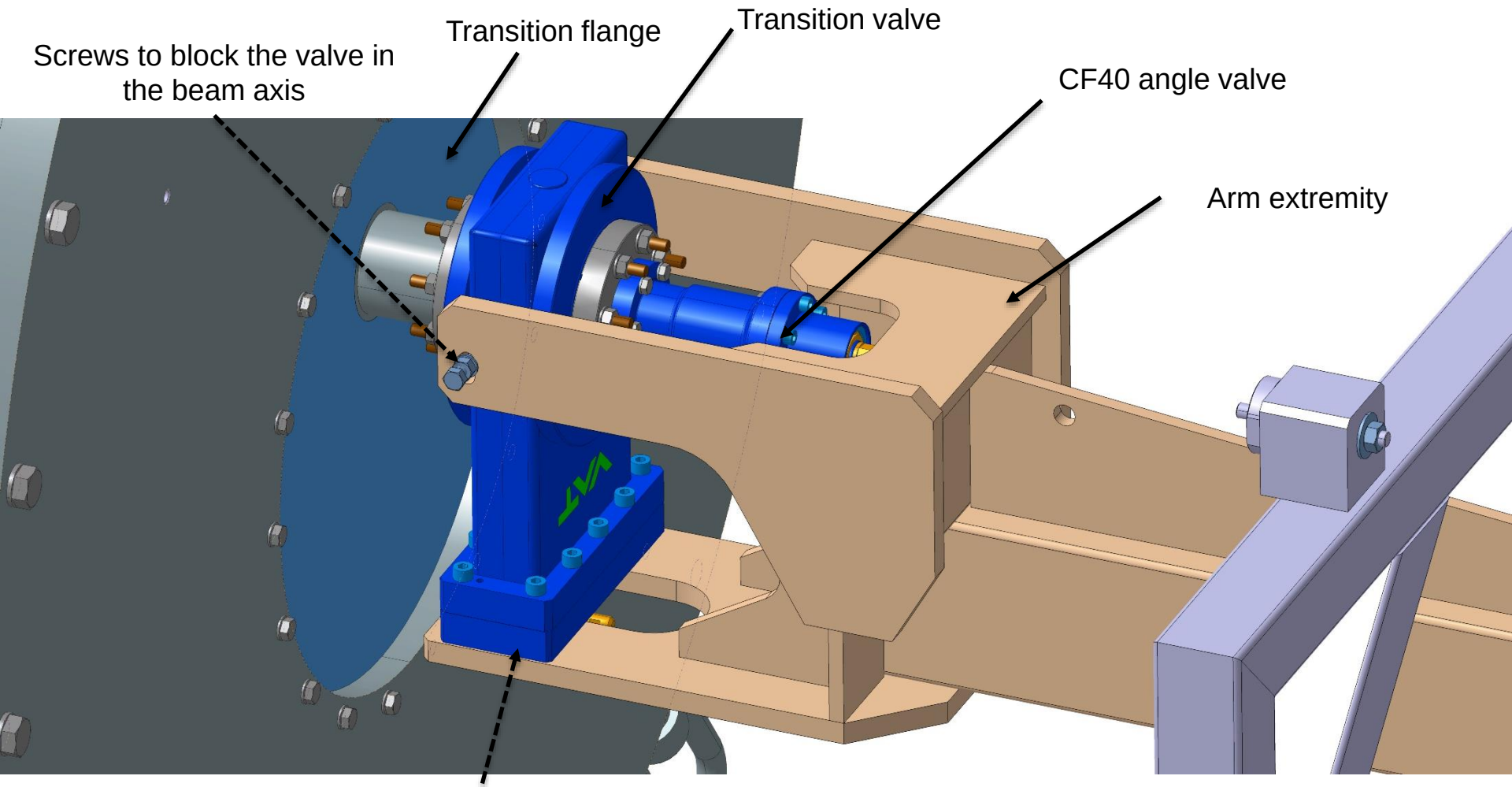
Charge 1a



Preliminary design of the tooling for PIP2 end cap assembly

Design of the arm extremity

Charge 1d



Degrees of freedom of the tooling

Charge 1d

! Warning !

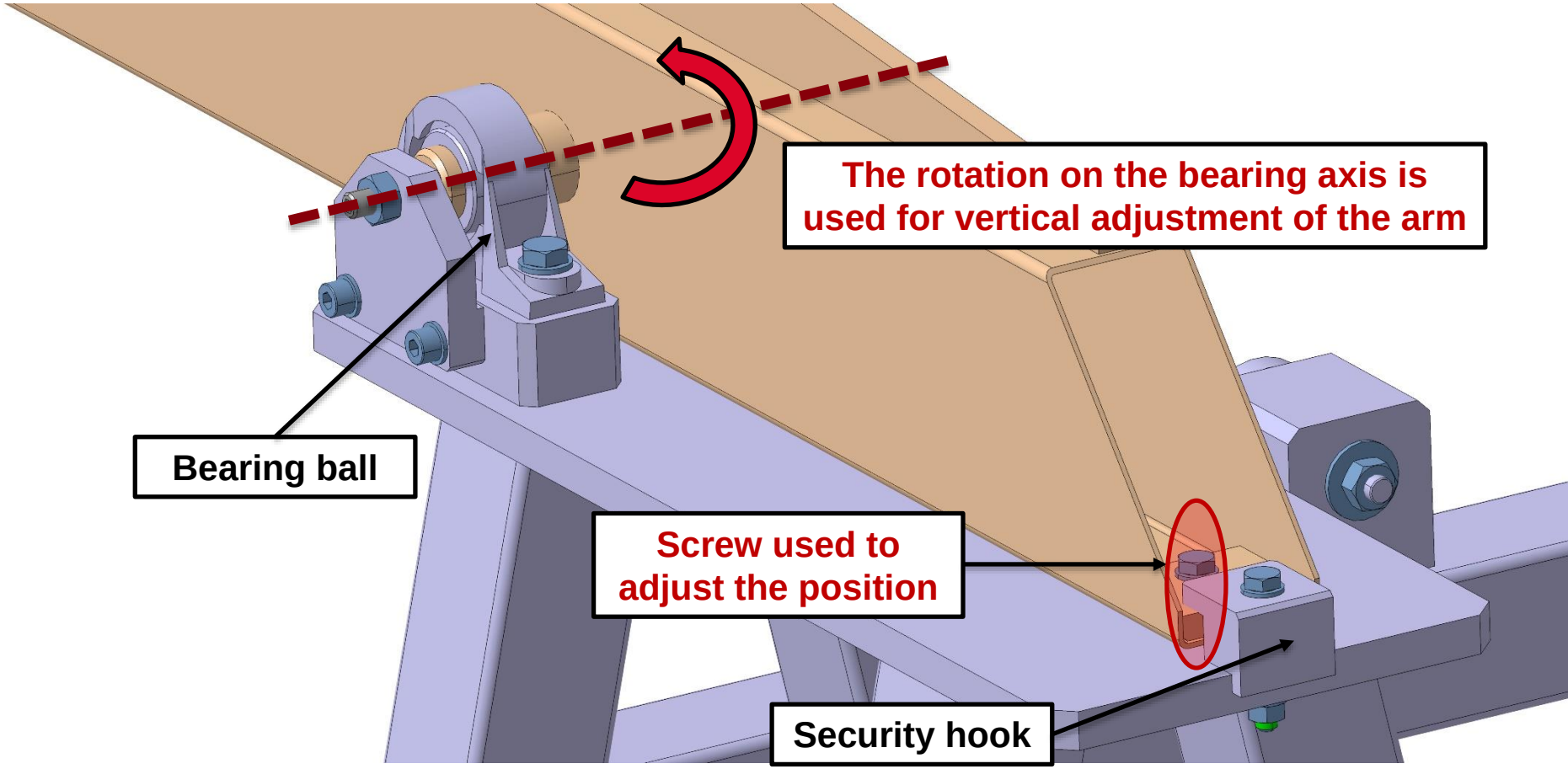
During the end cap assembly phase, the position of the transition valve is not modified.

The degrees of freedom of the tooling are used in order to ease the assembly of the valve with the tooling.

Then, when the weight of the valve is sustain by the tooling **no** adjustment of the valve positioning is done in order to avoid bellows twist and stress.

Degrees of freedom of the tooling

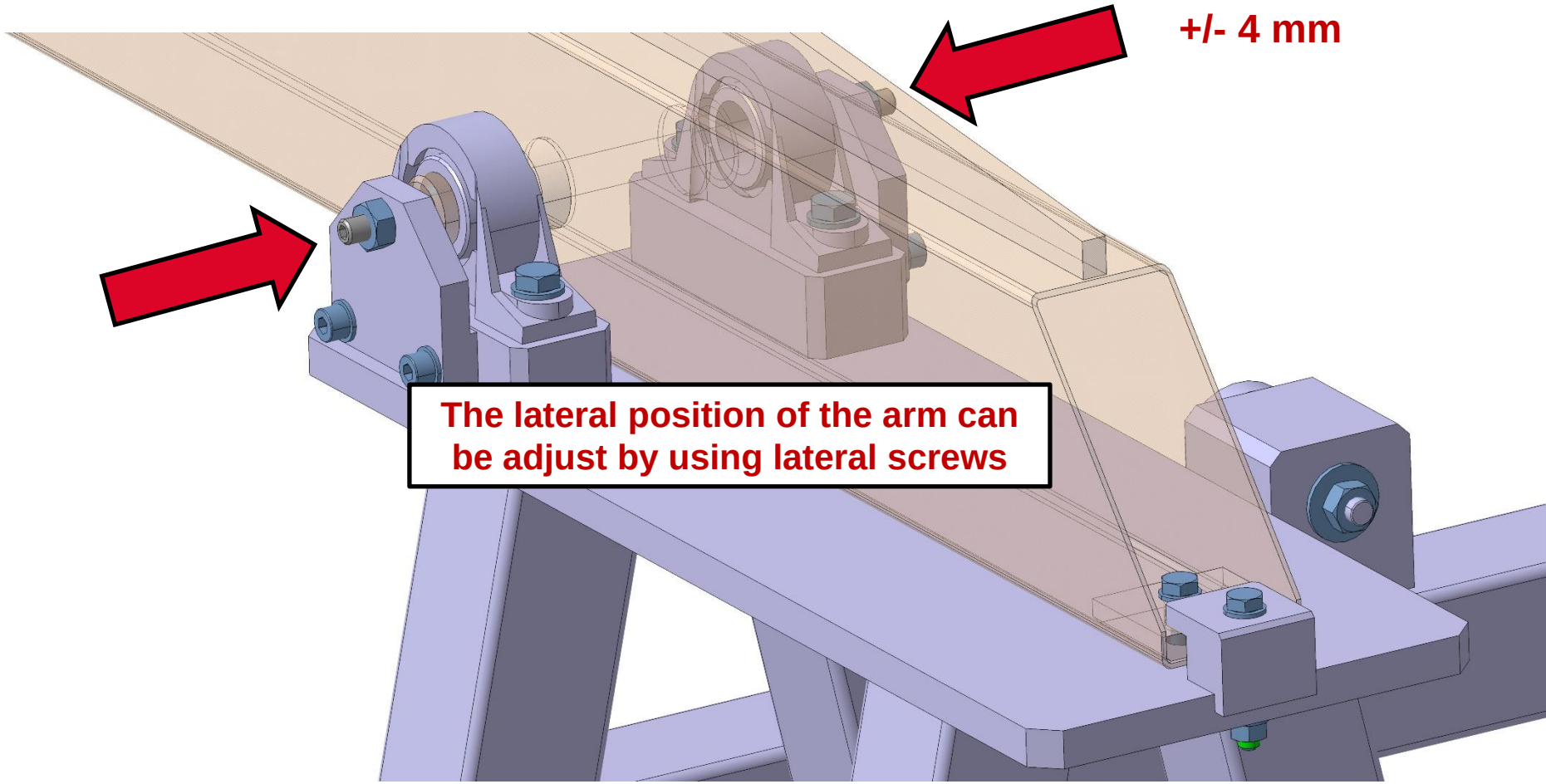
Charge 1d



Degrees of freedom of the tooling

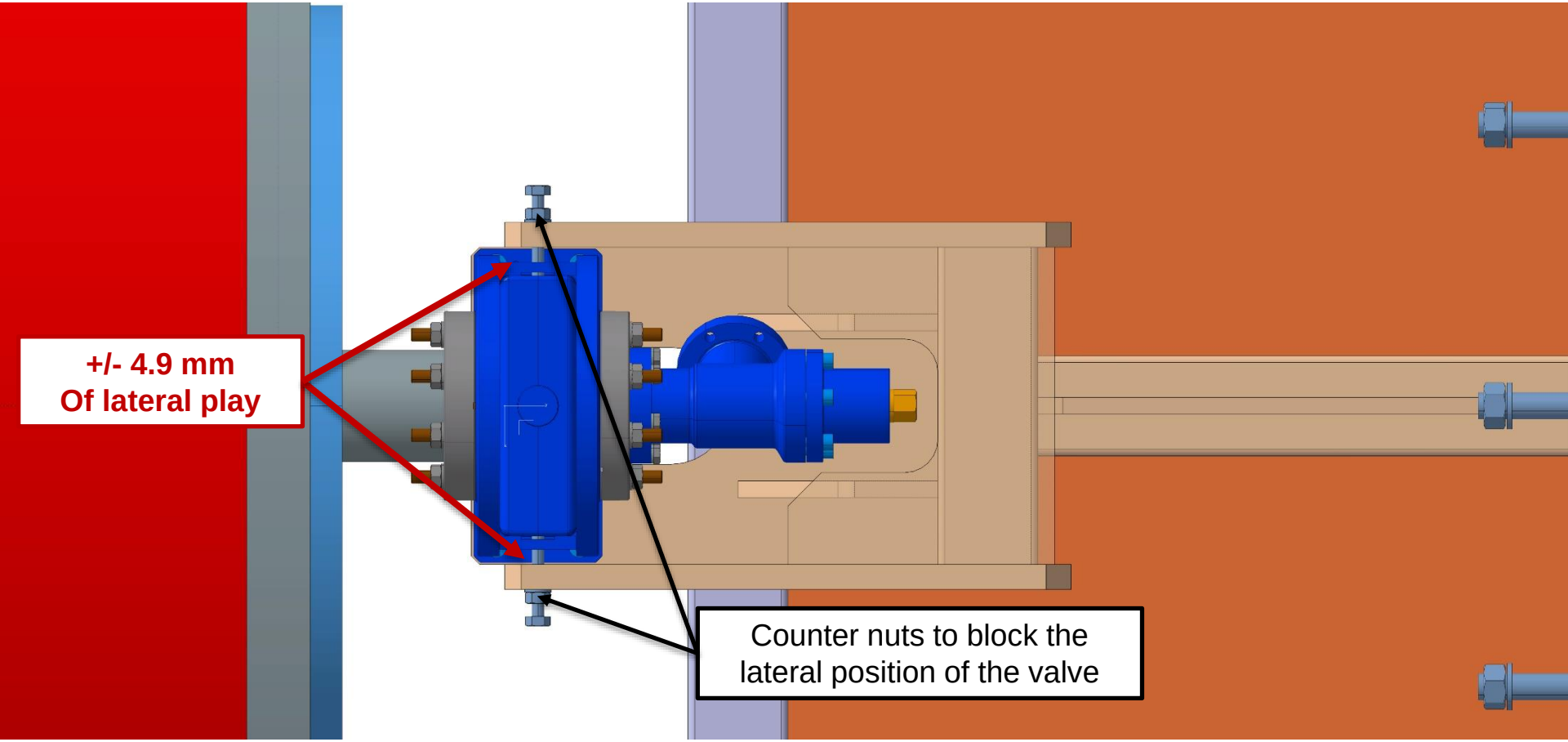
Charge 1d

+/- 4 mm



Degrees of freedom of the tooling

Charge 1d



Top view of the tooling

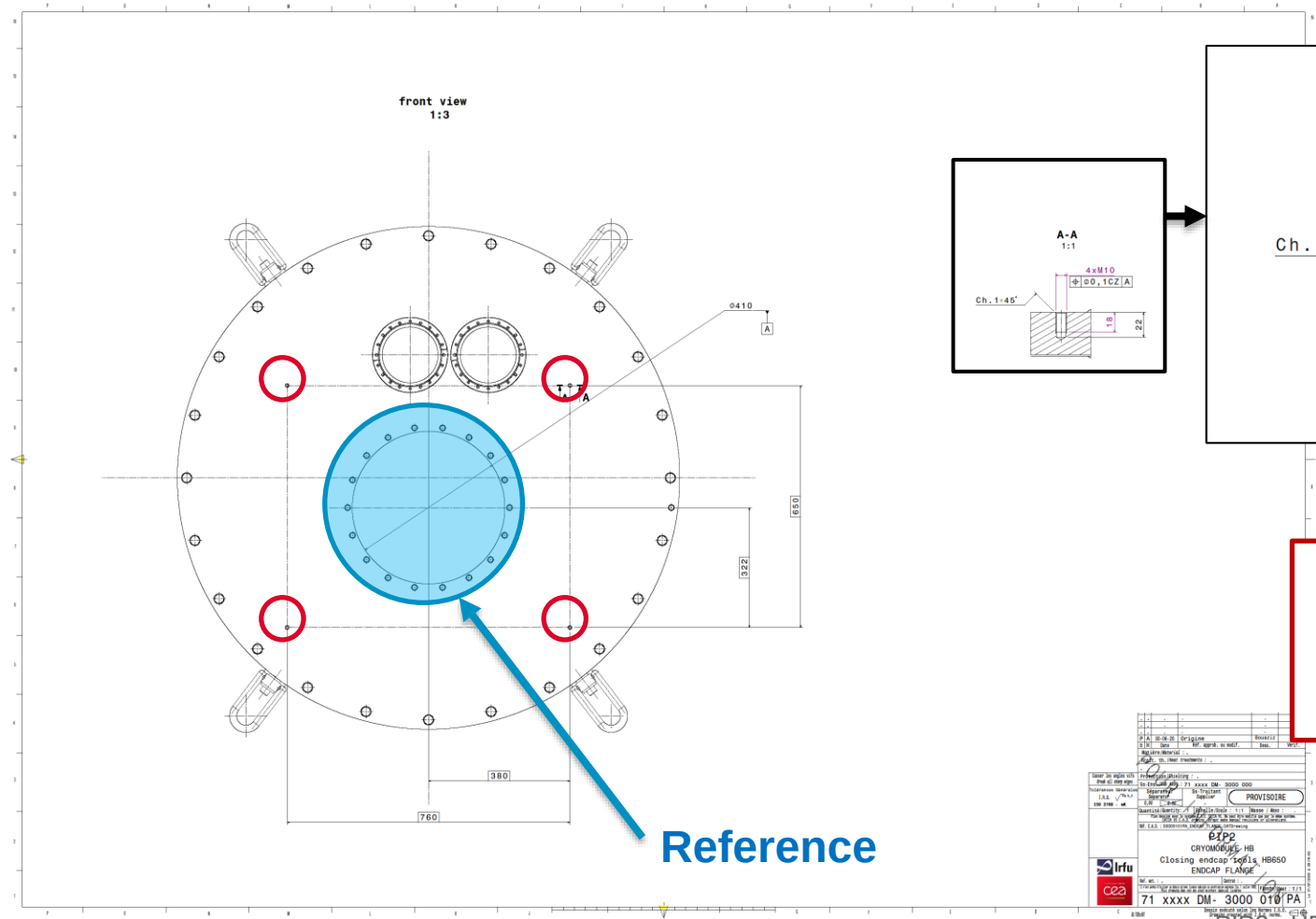
INTERFACES WITH THE HB650 CRYOMODULE

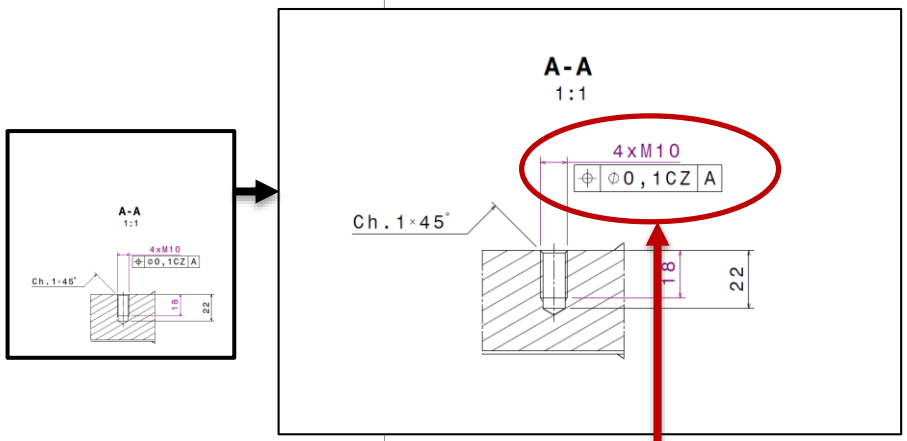
INTERFACES WITH THE HB650 CM

An interface drawing is ongoing.

- Four M10 threaded holes on the end cap.
- Cold-warm transition hole used as a reference.

Charge 1b





Still have some work to define the tolerances

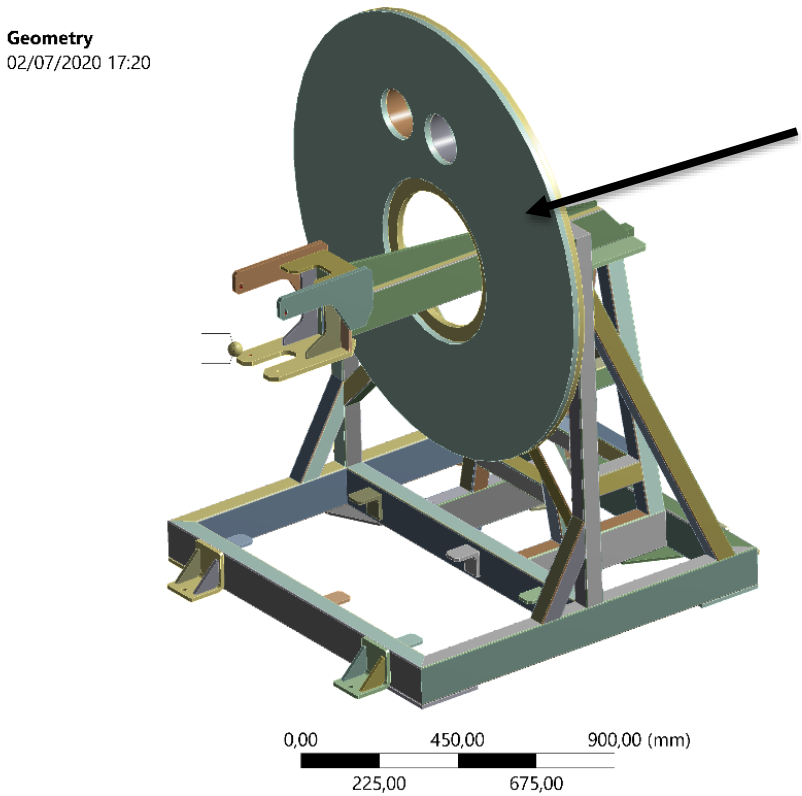
MECHANICAL SIMULATIONS

Four steps during the assembly were studied

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve
3. The tooling is holding only the transition valve
4. The tooling is without any mass

Assembly Of the CM



- ❑ The end cap is on the tooling
- ❑ The arm position is adjusted to the valve position
- ❑ The screws of the arm are in contact with the transition valve

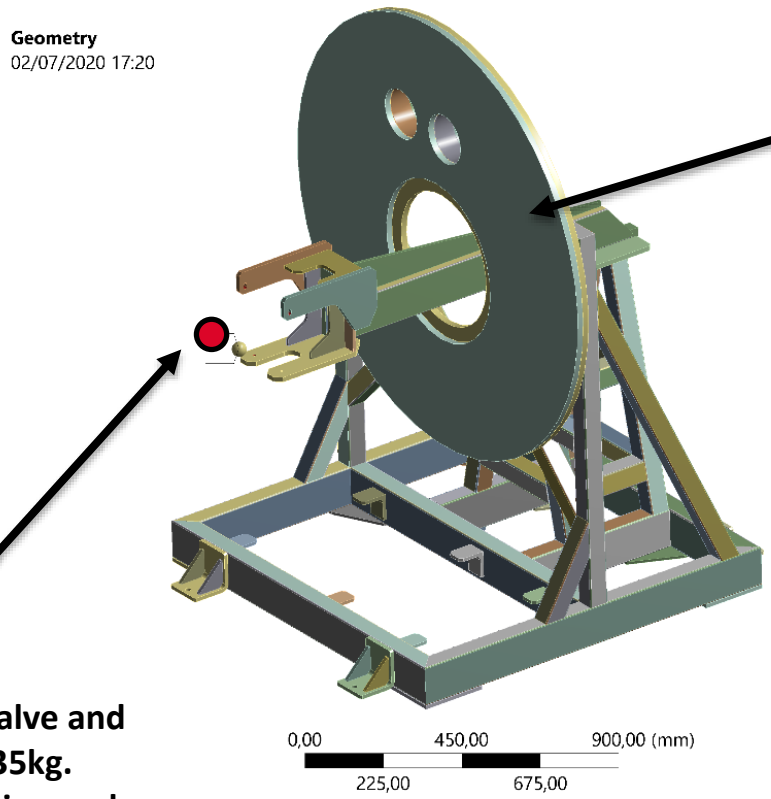
Step 1

Four steps during the assembly were studied

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve
3. The tooling is holding only the transition valve
4. The tooling is without any mass

Assembly
Of the CM



- The transition tooling is removed
- Thus, the weight of the transition is sustained by the end cap tooling

Mass of the transition valve and flange estimated at 35kg.
Assembly of the cavity string under vacuum (-285N on Y axis).

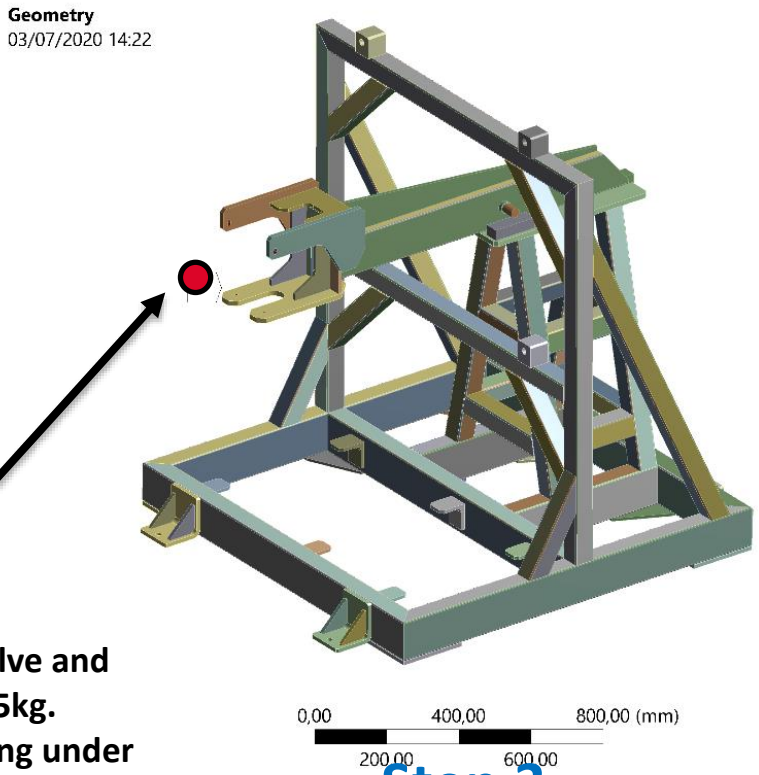
Step 2

Four steps during the assembly were studied

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

Assembly
Of the CM



- The end cap is lifted with the crane

Mass of the transition valve and flange estimated at 35kg.
Assembly of the cavity string under vacuum (-285N on Y axis).

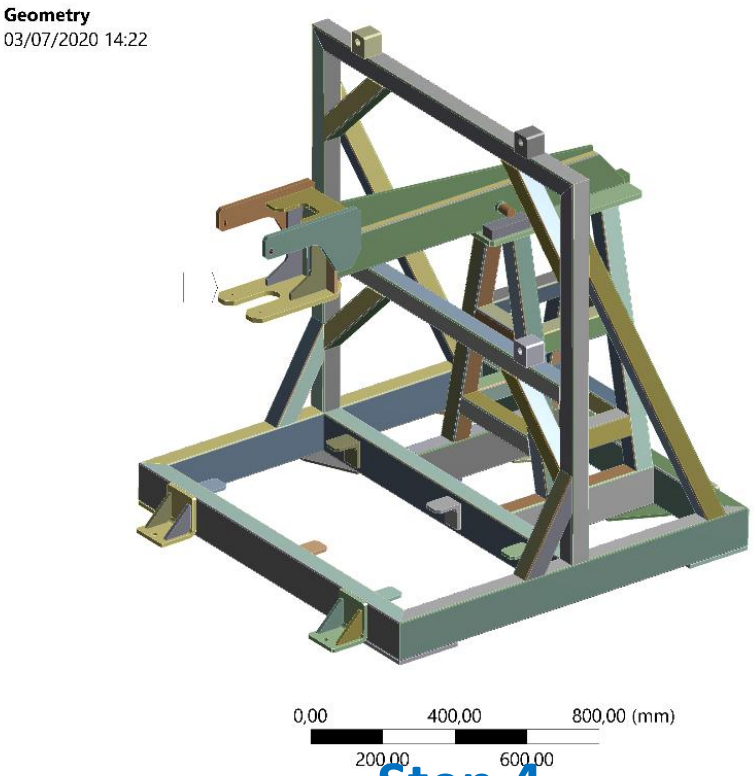
Step 3

Four steps during the assembly were studied

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

Assembly
Of the CM



Step 4

- The end cap is connected to the vacuum vessel and to the transition flange
- Thus, the arm do not sustain the weight of the transition.

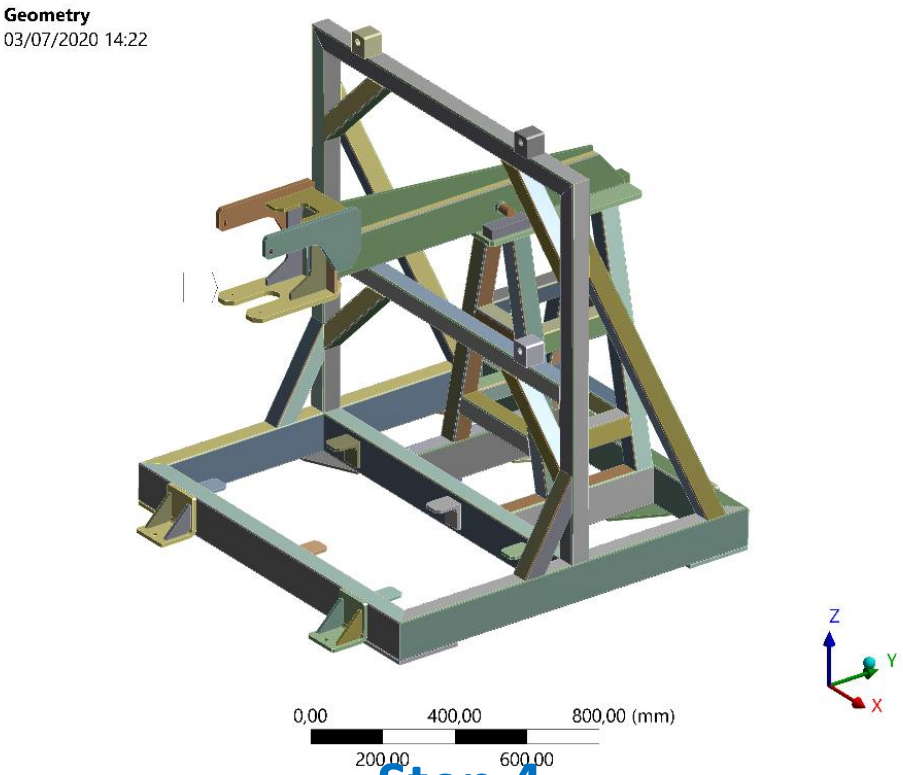
Four steps during the assembly were studied

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

Charge 1a

Assembly Of the CM

Disassembly Of the CM



Step 4

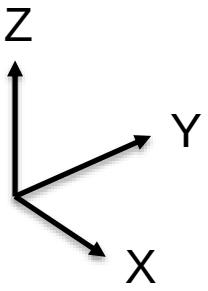
Output parameters

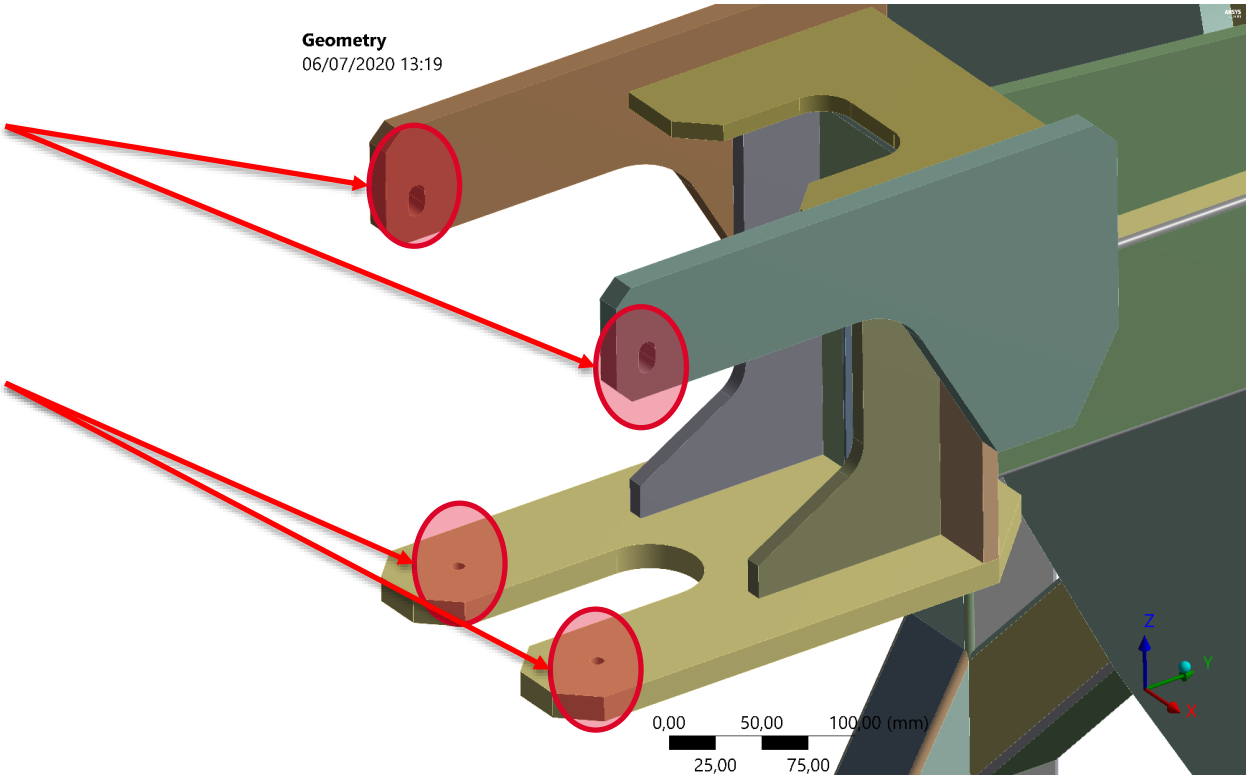
Charge 1a

Four arm interfaces with the transition valve are monitored.

Displacement on the Y axis (along beam axis)

Displacement on the Z axis (along vertical axis)





As the position of the arm is adjust to the valve transition at the **step 1**, its deformations at the monitored interface are used as a reference for the assembly (the deformations are used as offset).
During the disassembly **step 4** will be used as a reference.

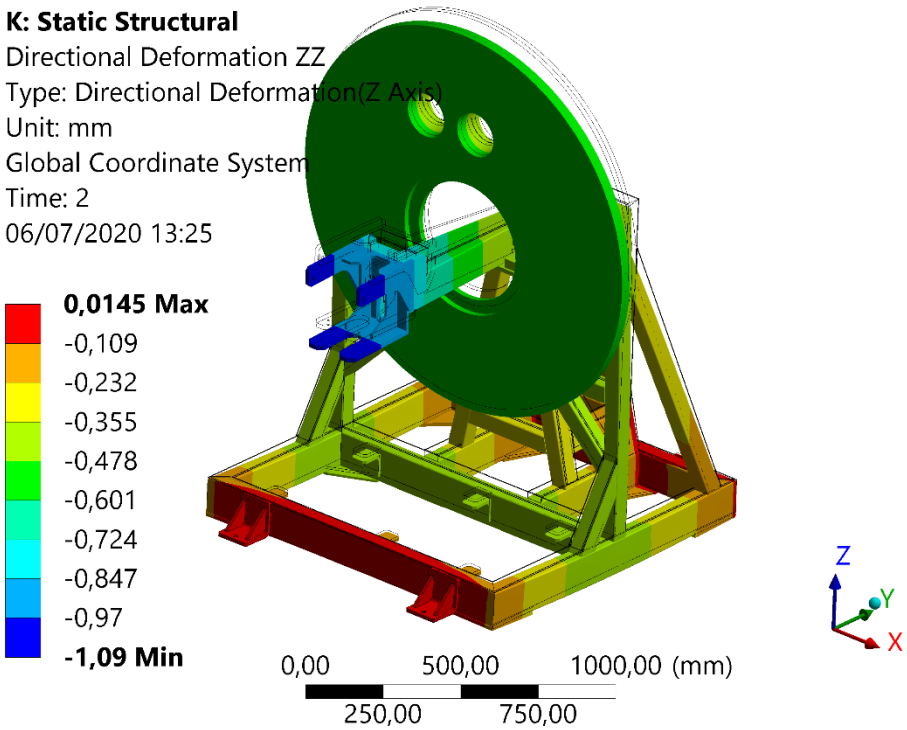
Preliminary results – Vertical deformations

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

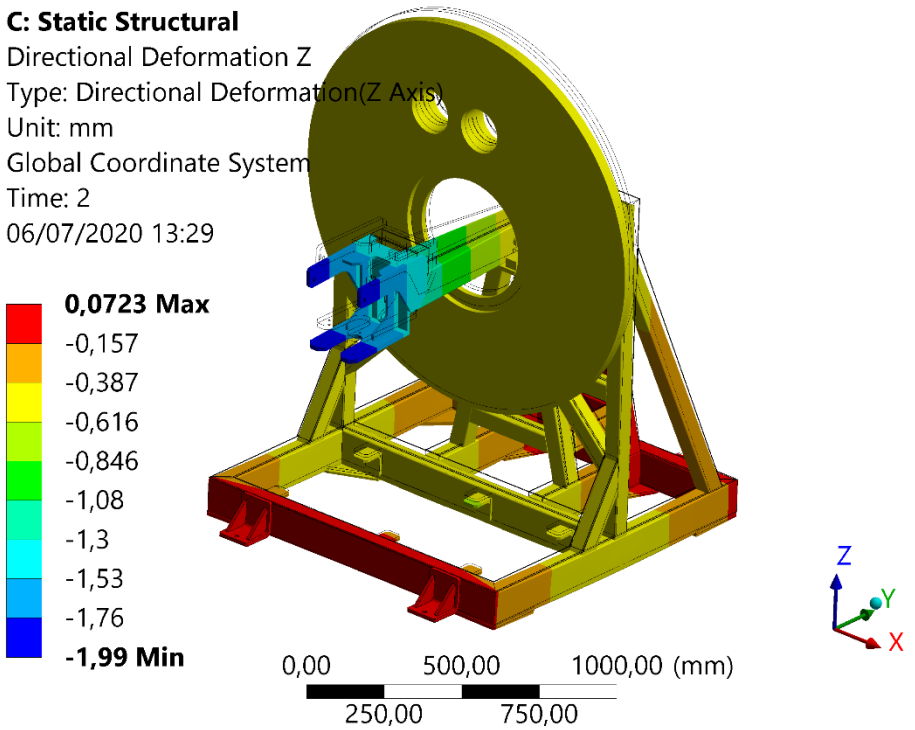
Step 1 (“Reference”)

Absolute vertical deformations



Step 2

Absolute vertical deformations



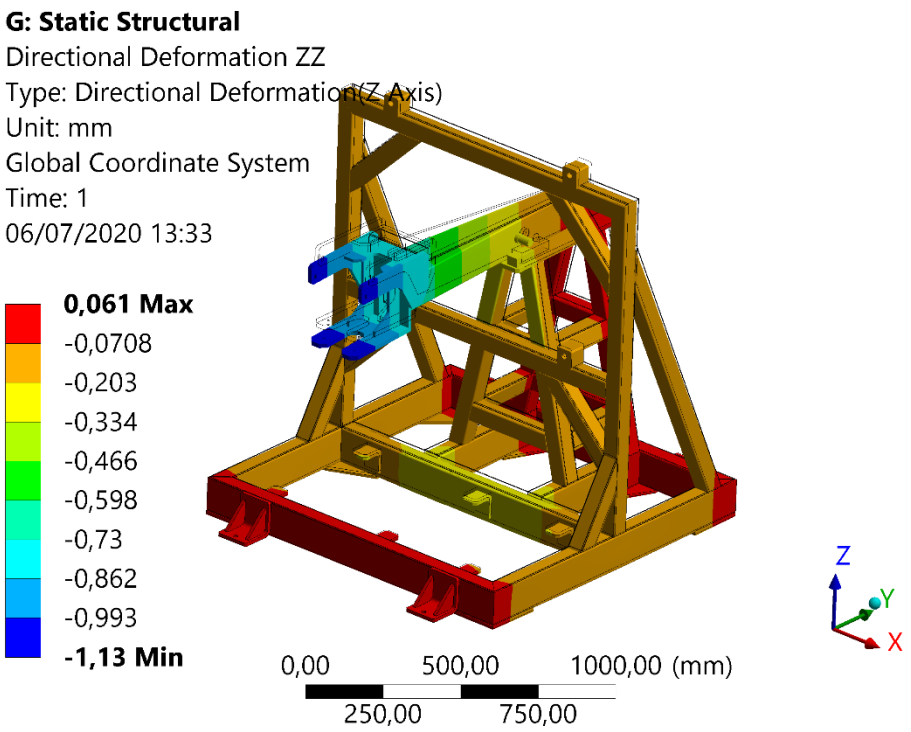
Preliminary results – Vertical deformations

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

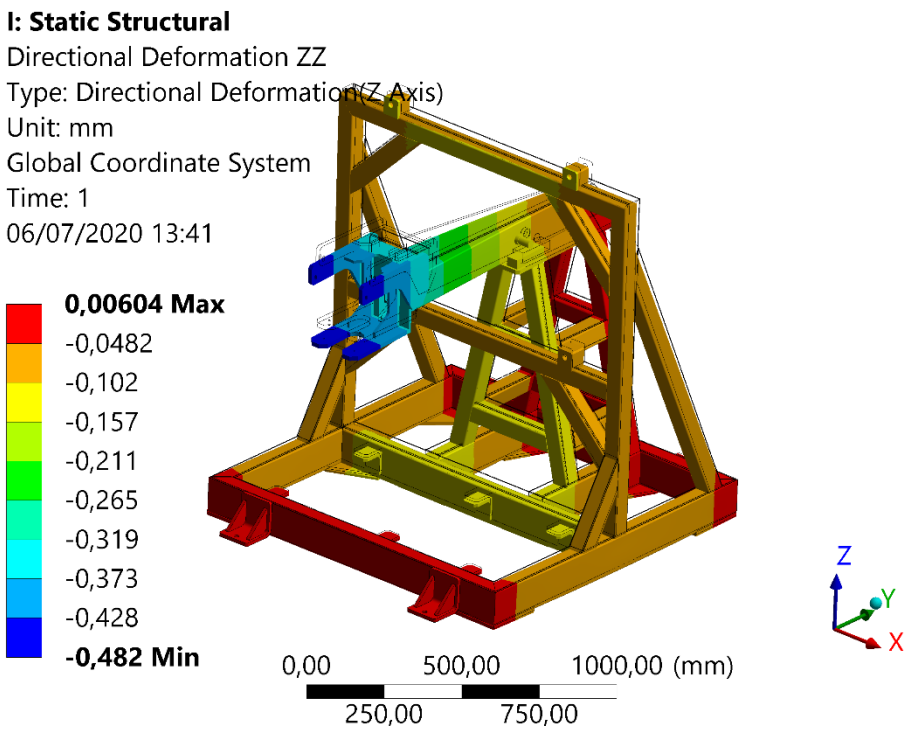
Step 3

Absolute vertical deformations



Step 4

Absolute vertical deformations



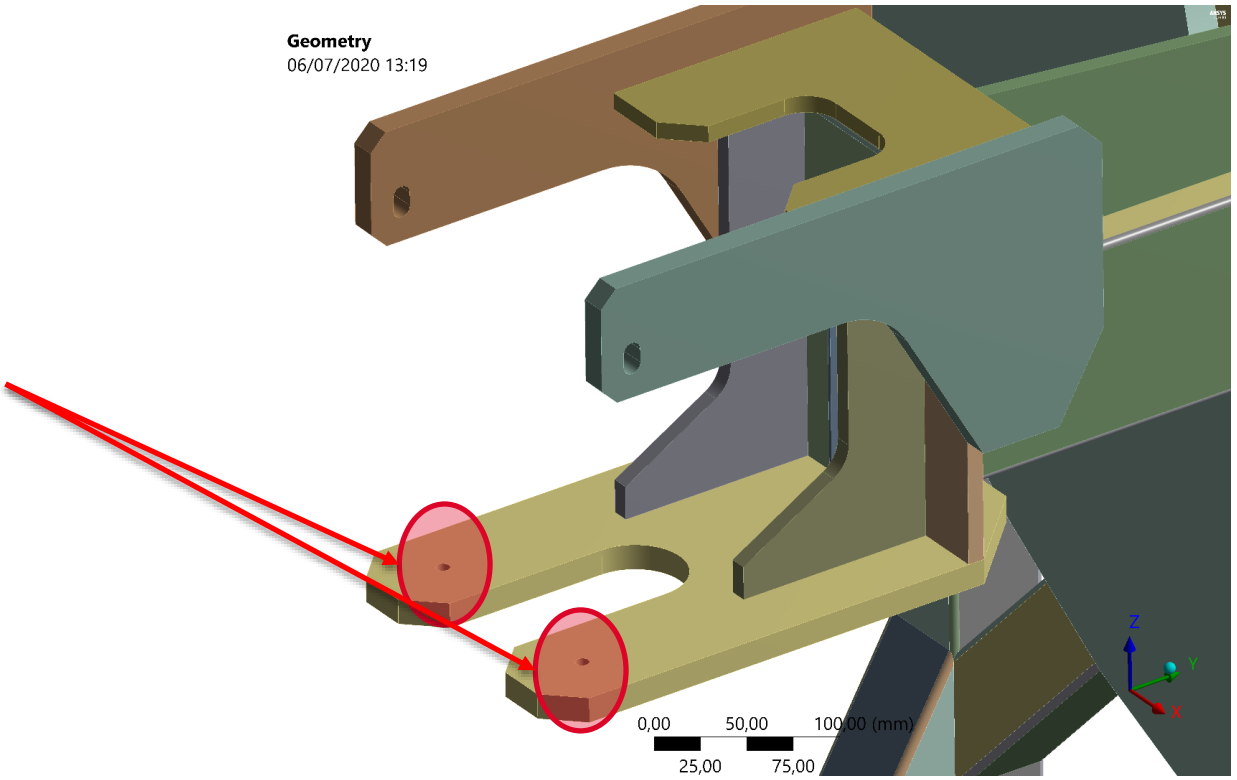
Preliminary results – Vertical deformations

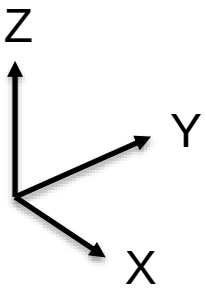
Charge 1a

Relative vertical displacement at the interfaces with the transition.

- Step 1 : **0 mm Reference** for the following steps (tooling with end cap)
- Step 2 : **-0.85 mm** (tooling with end cap and transition)
- Step 3 : **-0.01 mm** (tooling with transition)
- Step 4 : **+0.60 mm** (tooling only)

Displacement on the Z axis
(along vertical axis)





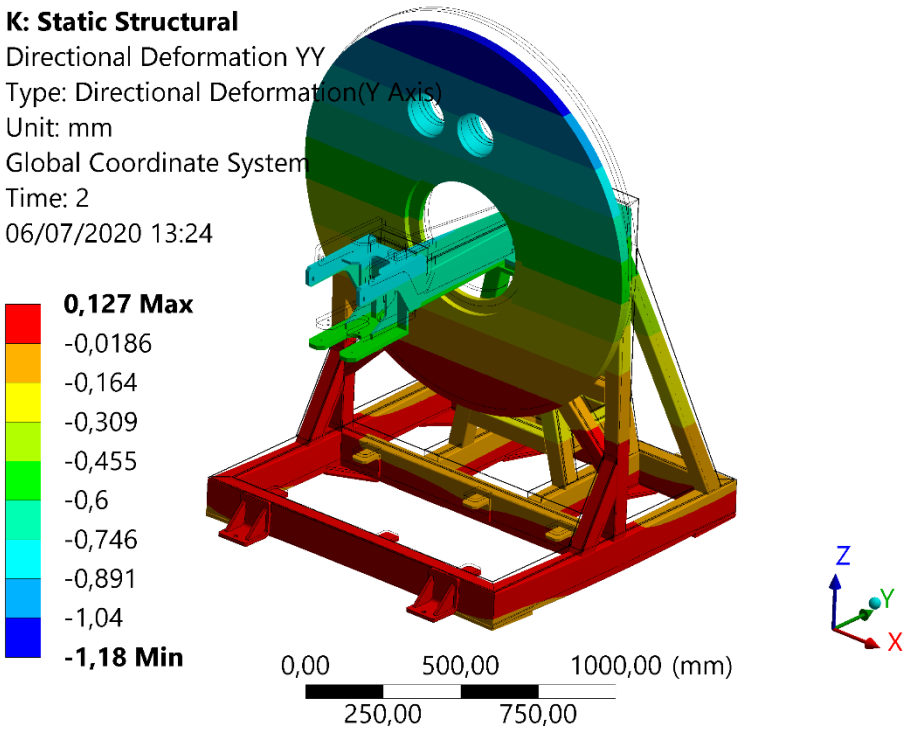
Preliminary results – Horizontal deformations

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

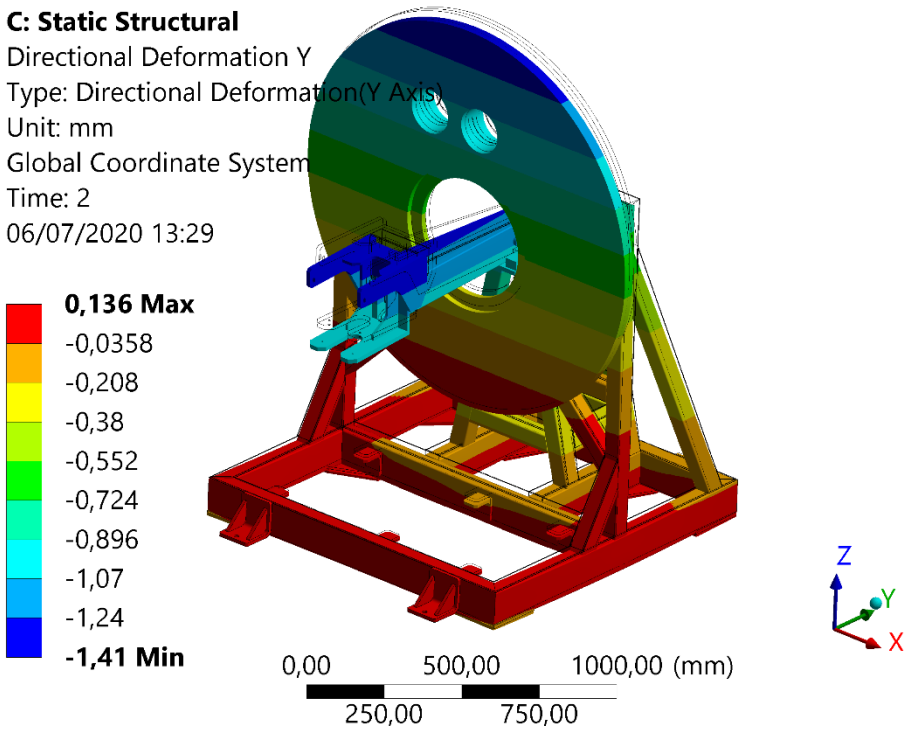
Step 1 (“Reference”)

Absolute horizontal deformations



Step 2

Absolute horizontal deformations



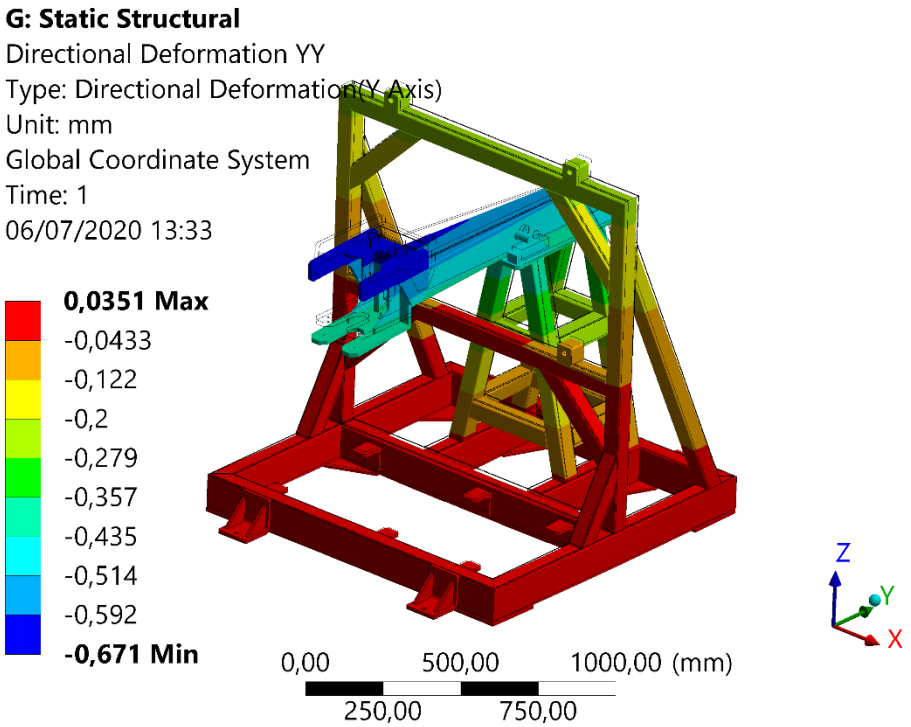
Preliminary results – Horizontal deformations

Charge 1a

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

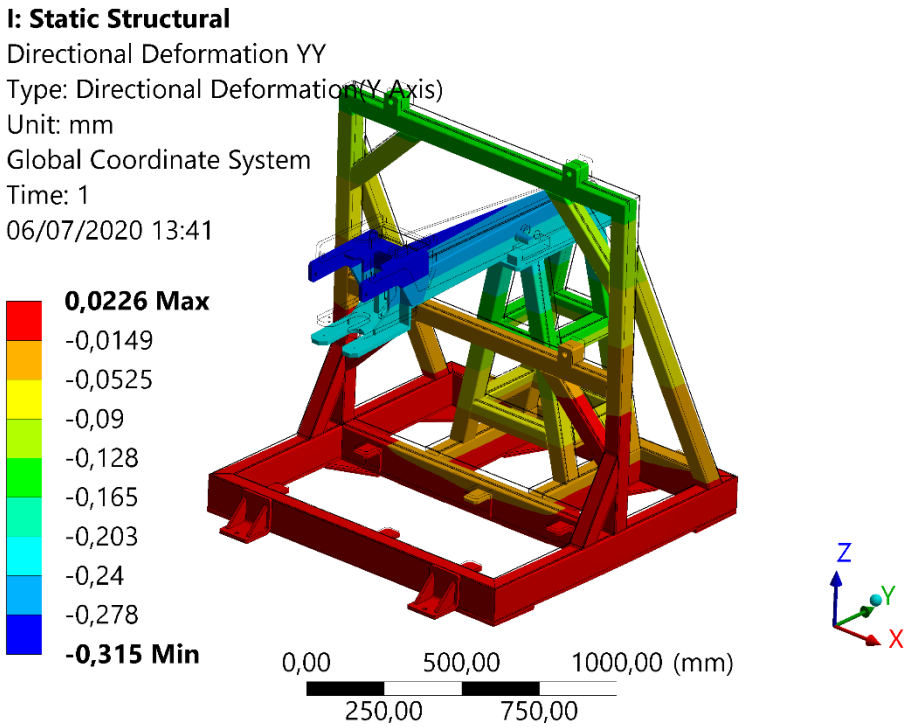
Step 3

Absolute horizontal deformations



Step 4

Absolute horizontal deformations



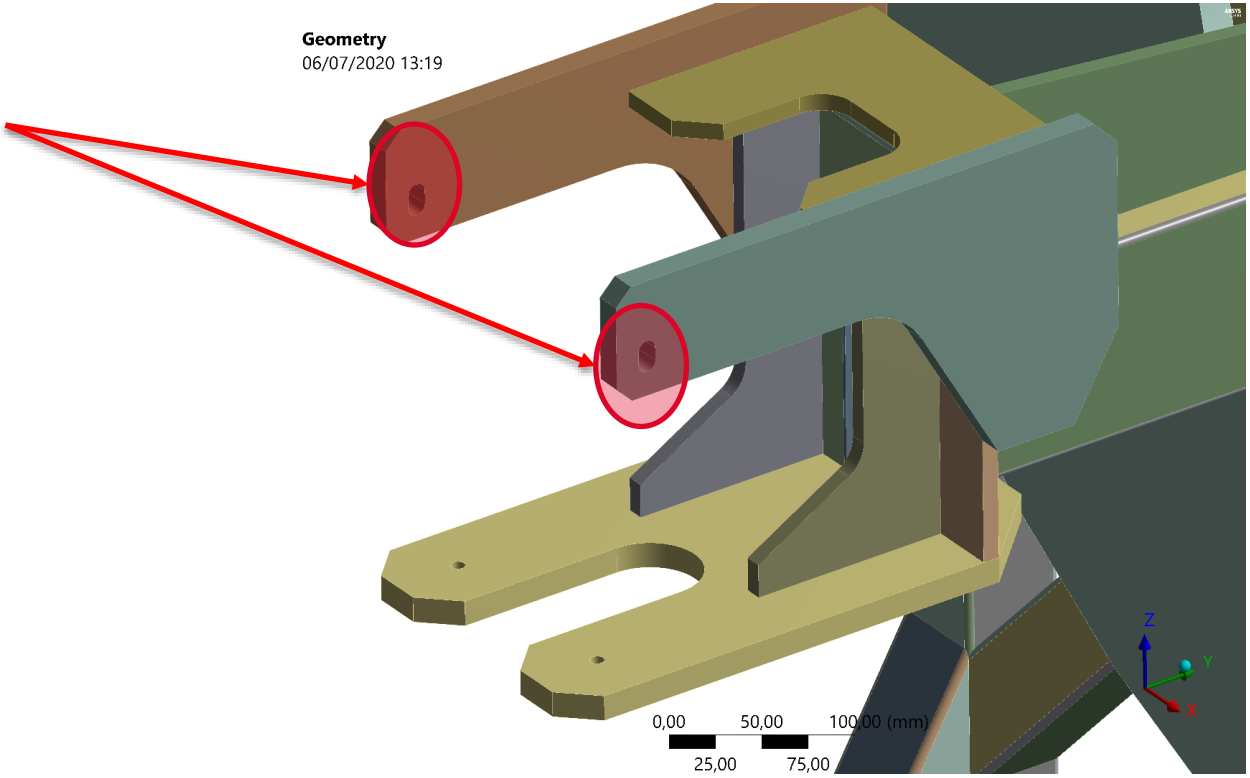
Preliminary results – Horizontal deformations

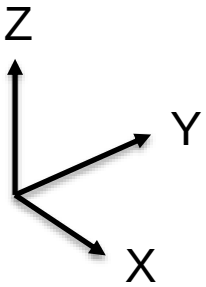
Charge 1a

Relative horizontal displacement at the interfaces with the transition.

- Step 1 : **0 mm** **Reference** for the following steps (tooling with end cap)
- Step 2 : **-0.57 mm** (tooling with end cap and transition)
- Step 3 : **+0.14 mm** (tooling with transition)
- Step 4 : **+0.46 mm** (tooling only)

Displacement on the Y axis
(along beam axis)



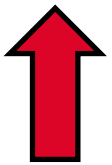


Four steps for the assembly were studied

1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

Charge 1a

Assembly Of the CM



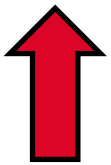
Disassembly Of the CM

Four steps for the assembly were studied

Charge 1a

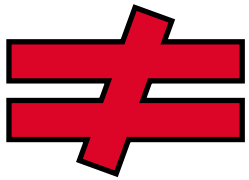
1. The tooling is holding the end cap.
2. The tooling is holding the end cap and the transition valve.
3. The tooling is holding only the transition valve.
4. The tooling is without any mass.

Assembly
Of the CM

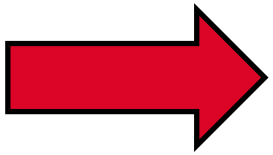


Disassembly
Of the CM

ASSEMBLY



DISASSEMBLY



Because the adjustment of the arm position is done at step 1 for the assembly and at step 4 for the disassembly. They don't have the same "reference".

Summary of the results – Displacement at the interfaces

Charge 1a

Vertical displacement at the interfaces with the transition.

- Step 1 : **0 mm** (**Reference** for the assembly)
- Step 2 : **-0.85 mm**
- Step 3 : **-0.01 mm**
- Step 4 : **+0.60mm**

Horizontal displacement at the interfaces with the transition.

- Step 1 : **0 mm** (**Reference** for the assembly)
- Step 2 : **-0.57 mm**
- Step 3 : **+0.14 mm**
- Step 4 : **+0.46 mm**

Summary of the results – Displacement at the interfaces

Charge 1a

Vertical displacement at the interfaces with the transition.

- Step 1 : **0 mm** (**Reference** for the assembly)
- Step 2 : **-0.85 mm**
- Step 3 : **-0.01 mm**
- Step 4 : **+0.60mm**

Assembly Step 1→3

- **The end cap is assembled to the transition flange and vacuum vessel.**
- **Thus, the deformations of the tooling at step 4 has no impact on the transition.**

Horizontal displacement at the interfaces with the transition.

- Step 1 : **0 mm** (**Reference** for the assembly)
- Step 2 : **-0.57 mm**
- Step 3 : **+0.14 mm**
- Step 4 : **+0.46 mm**

Assembly Step 1→3

- **The end cap is assembled to the transition flange and vacuum vessel.**
- **Thus, the deformations of the tooling at step 4 has no impact on the transition.**

Summary of the results – Displacement at the interfaces

Charge 1a

Vertical displacement at the interfaces with the transition.

Range of displacement during assembly **0.85 mm**

- Step 1 : **0 mm** (**Reference** for the assembly)
- Step 2 : **-0.85 mm**
- Step 3 : **-0.01 mm**
- Step 4 : **+0.60mm**

Assembly Step 1→3

- **The end cap is assembled to the transition flange and vacuum vessel.**
- **Thus, the deformations of the tooling at step 4 has no impact on the transition.**

Horizontal displacement at the interfaces with the transition.

Range of displacement during assembly **0.71 mm**

- Step 1 : **0 mm** (**Reference** for the assembly)
- Step 2 : **-0.57 mm**
- Step 3 : **+0.14 mm**
- Step 4 : **+0.46 mm**

Assembly Step 1→3

- **The end cap is assembled to the transition flange and vacuum vessel.**
- **Thus, the deformations of the tooling at step 4 has no impact on the transition.**

Summary of the results – Displacement at the interfaces

Charge 1a

Vertical displacement at the interfaces with the transition.

- Step 1 : **0 mm**
- Step 2 : **-0.85 mm**
- Step 3 : **-0.01 mm**
- Step 4 : **+0.60mm** (**Reference** for the disassembly)

Horizontal displacement at the interfaces with the transition.

- Step 1 : **0 mm**
- Step 2 : **-0.57 mm**
- Step 3 : **+0.14 mm**
- Step 4 : **+0.46 mm** (**Reference** for the disassembly)

Summary of the results – Displacement at the interfaces

Charge 1a

Vertical displacement at the interfaces with the transition.

- Step 1 : 0 mm
- Step 2 : **-0.85 mm**
- Step 3 : **-0.01 mm**
- Step 4 : **+0.60mm** (**Reference** for the disassembly)

Disassembly Step 4→2

- **The transition valve is assembled to the transition tooling.**
- **Thus, the deformations of the tooling at step 1 has no impact on the transition during the disassembly.**

Horizontal displacement at the interfaces with the transition.

- Step 1 : 0 mm
- Step 2 : **-0.57 mm**
- Step 3 : **+0.14 mm**
- Step 4 : **+0.46 mm** (**Reference** for the disassembly)

Disassembly Step 4→2

- **The transition valve is assembled to the transition tooling.**
- **Thus, the deformations of the tooling at step 1 has no impact on the transition during the disassembly.**

Summary of the results – Displacement at the interfaces

Charge 1a

Vertical displacement at the interfaces with the transition.

Range of displacement during disassembly **1.45 mm**

- Step 1 : 0 mm
- Step 2 : **-0.85 mm**
- Step 3 : **-0.01 mm**
- Step 4 : **+0.60mm** (**Reference** for the disassembly)

Disassembly Step 4→2

- **The transition valve is assembled to the transition tooling.**
- **Thus, the deformations of the tooling at step 1 has no impact on the transition during the disassembly.**

Horizontal displacement at the interfaces with the transition.

Range of displacement during disassembly **1.03 mm**

- Step 1 : 0 mm
- Step 2 : **-0.57 mm**
- Step 3 : **+0.14 mm**
- Step 4 : **+0.46 mm** (**Reference** for the disassembly)

Disassembly Step 4→2

- **The transition valve is assembled to the transition tooling.**
- **Thus, the deformations of the tooling at step 1 has no impact on the transition during the disassembly.**

CONCLUSION
AND
FURTHER WORK

CONCLUSION

Work done

- Preliminary design is done and based on ESS experience.

- Preliminary simulations were performed in order to estimate the tooling deformations,
  - during assembly the vertical and lateral displacements of the interfaces are under 1mm.
  - during the disassembly the vertical and lateral displacements of the interfaces are over 1mm.

Work on going

- Define the tolerances for the end cap interfaces.

- Iteration with Fermilab to check if no collision appear with another tooling (transition tooling).

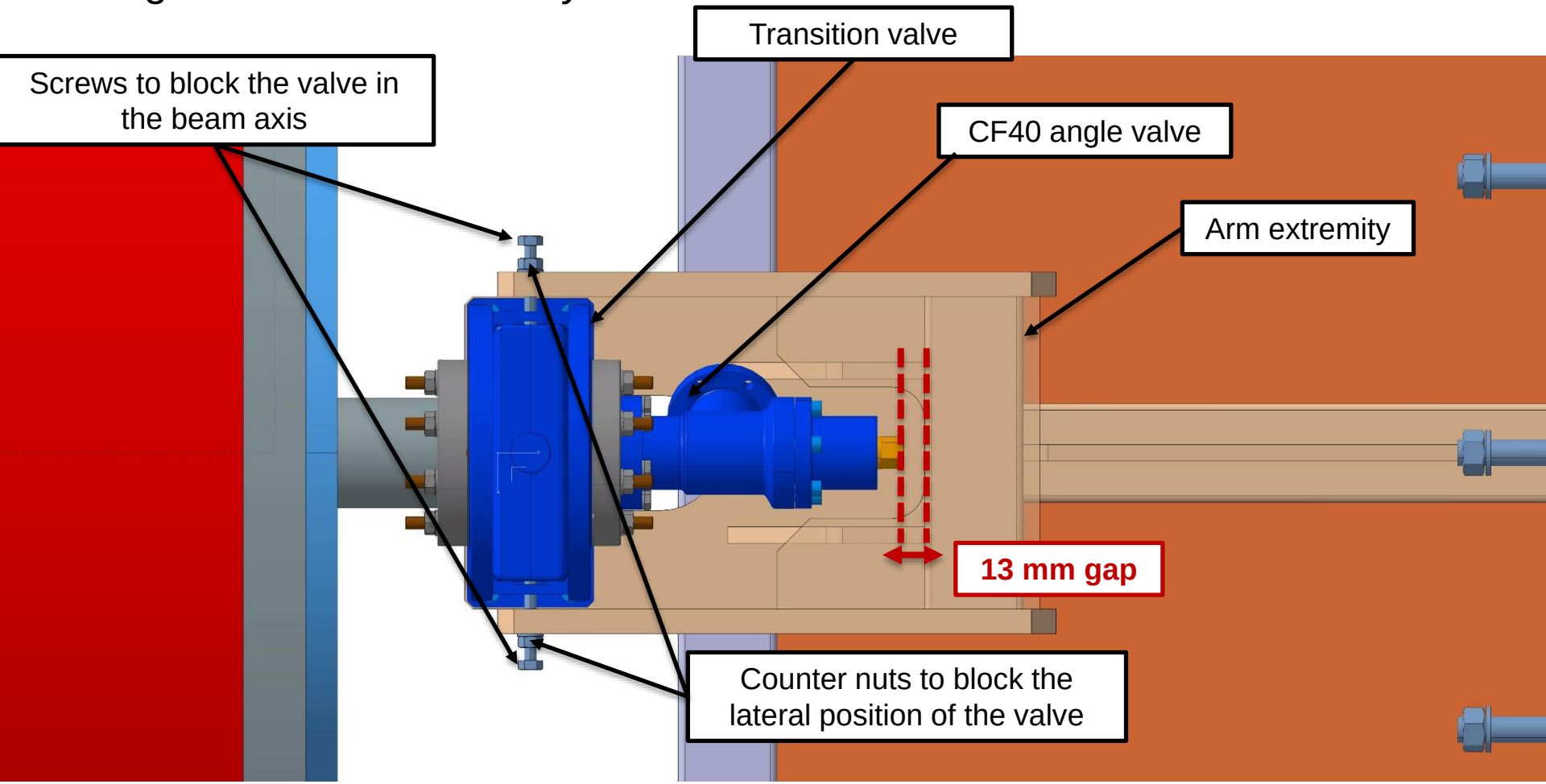
- Define the maximal admissible deformation at the arm extremity.

THANK YOU
FOR YOUR ATTENTION

BACK UP SLIDES

Preliminary design of the tooling for PIP2 end cap assembly

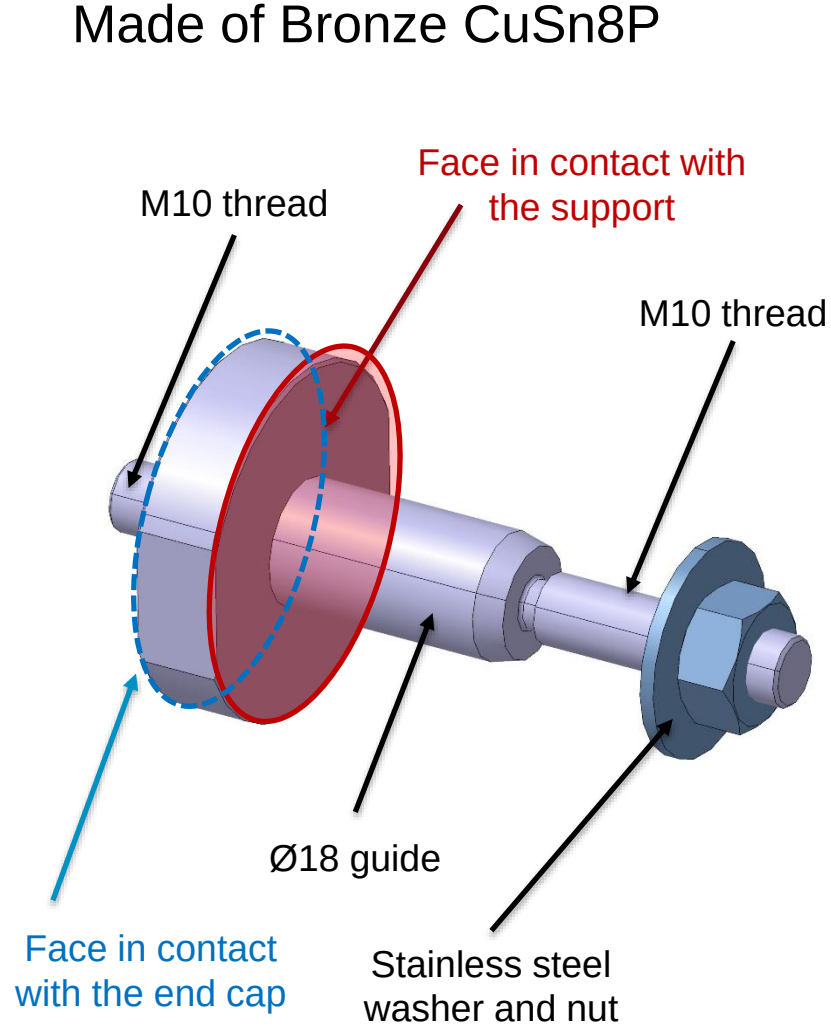
Design of the arm extremity

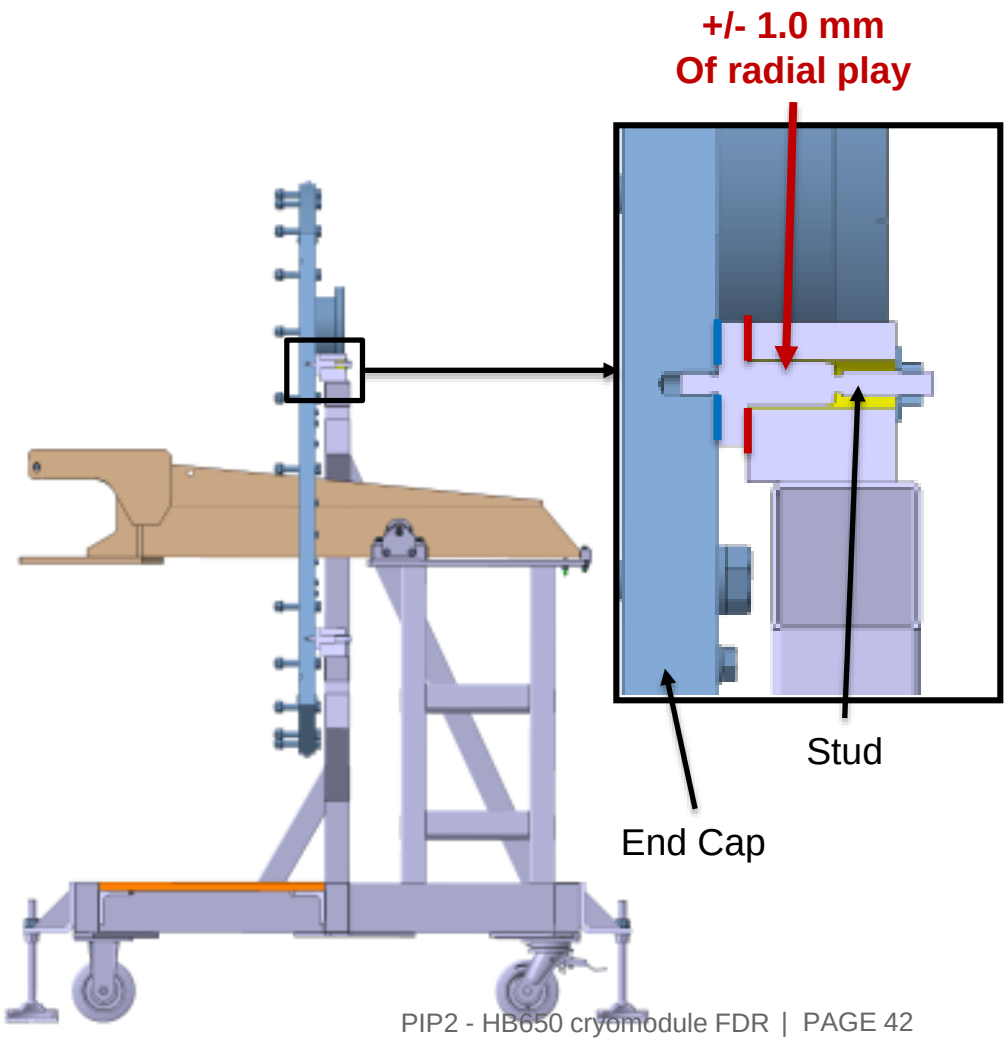


Top view of the tooling

Preliminary design of the tooling for PIP2 end cap assembly

Bronze studs are used for the maintaining of the end cap on the support.
Made of Bronze CuSn8P

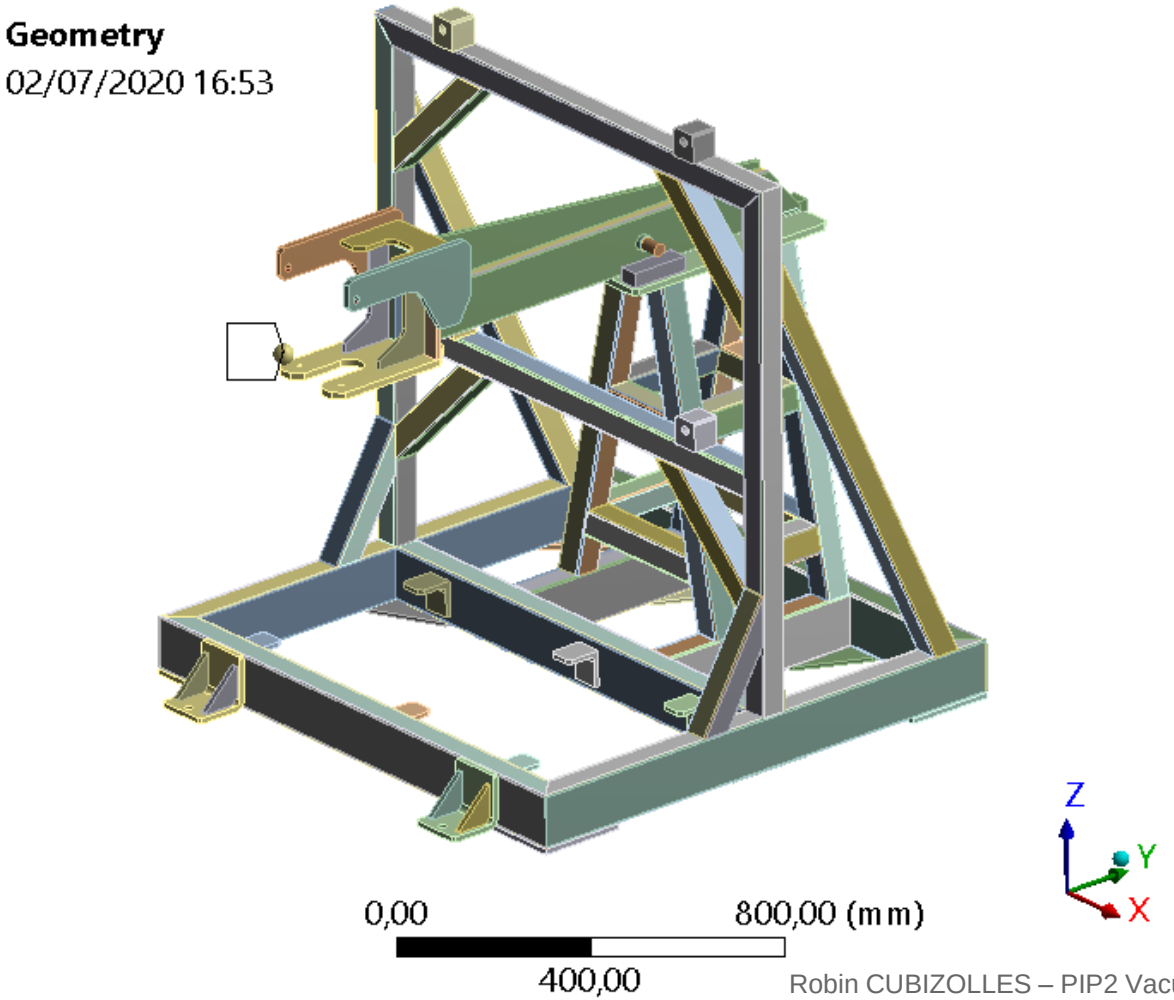




END CAP TOOLING

Model

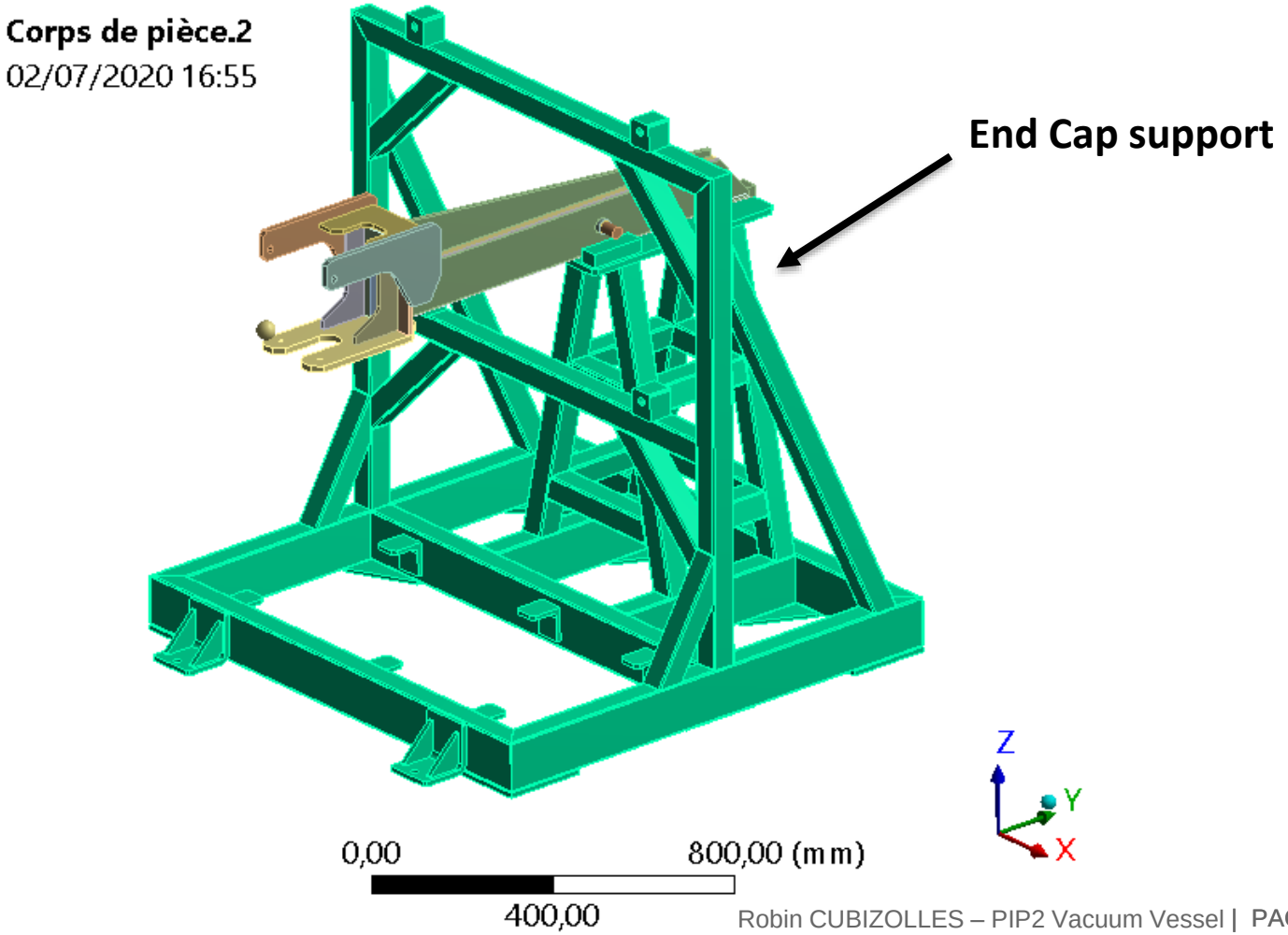
Tooling made of S275 Steel. The end cap is not attached to the tooling and the weight of the transition is supported by the tooling arm.



END CAP TOOLING

Model

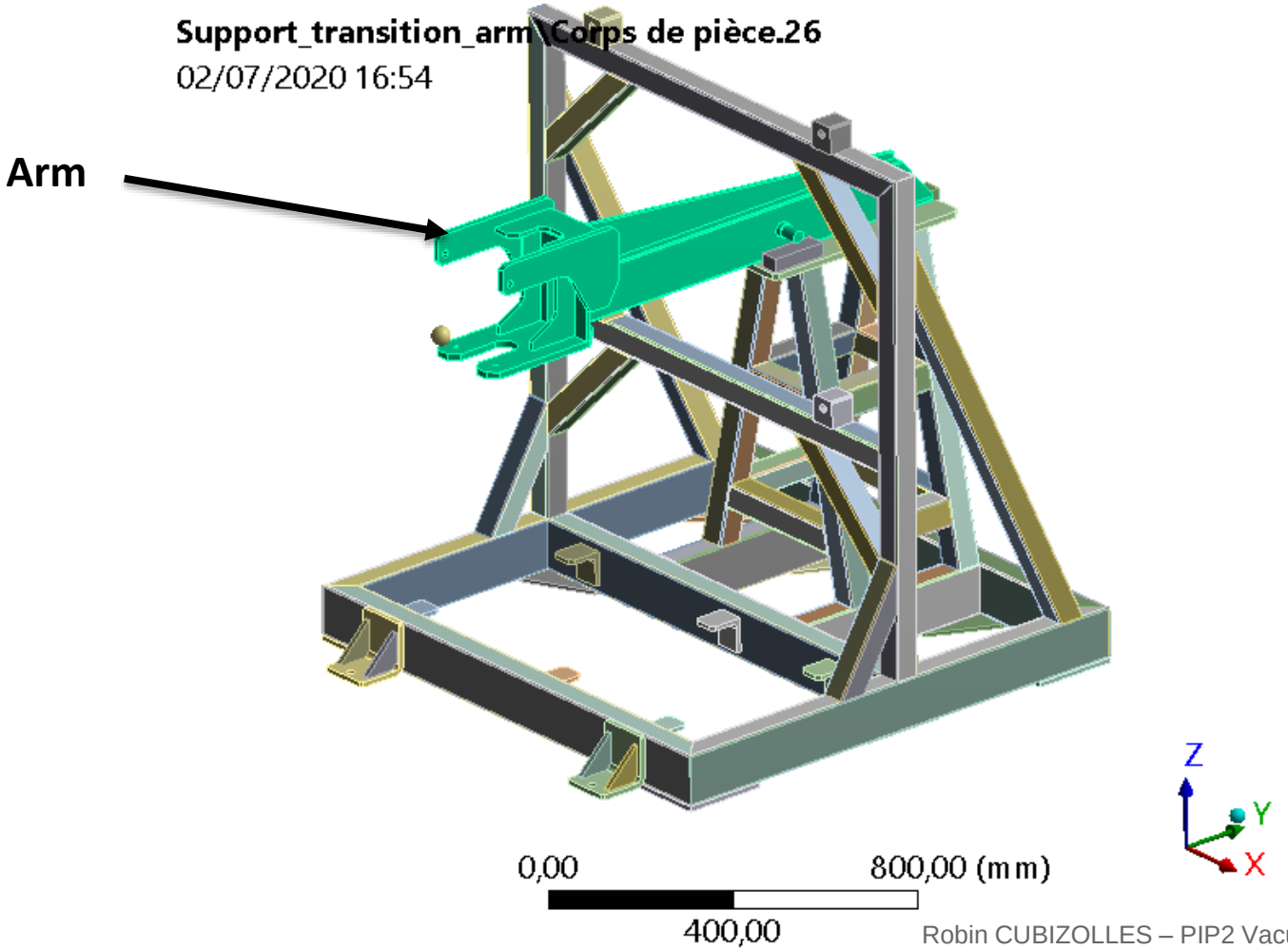
Tooling made of S275 Steel. The end cap is not attached to the tooling and the weight of the transition is supported by the tooling arm.



END CAP TOOLING

Model

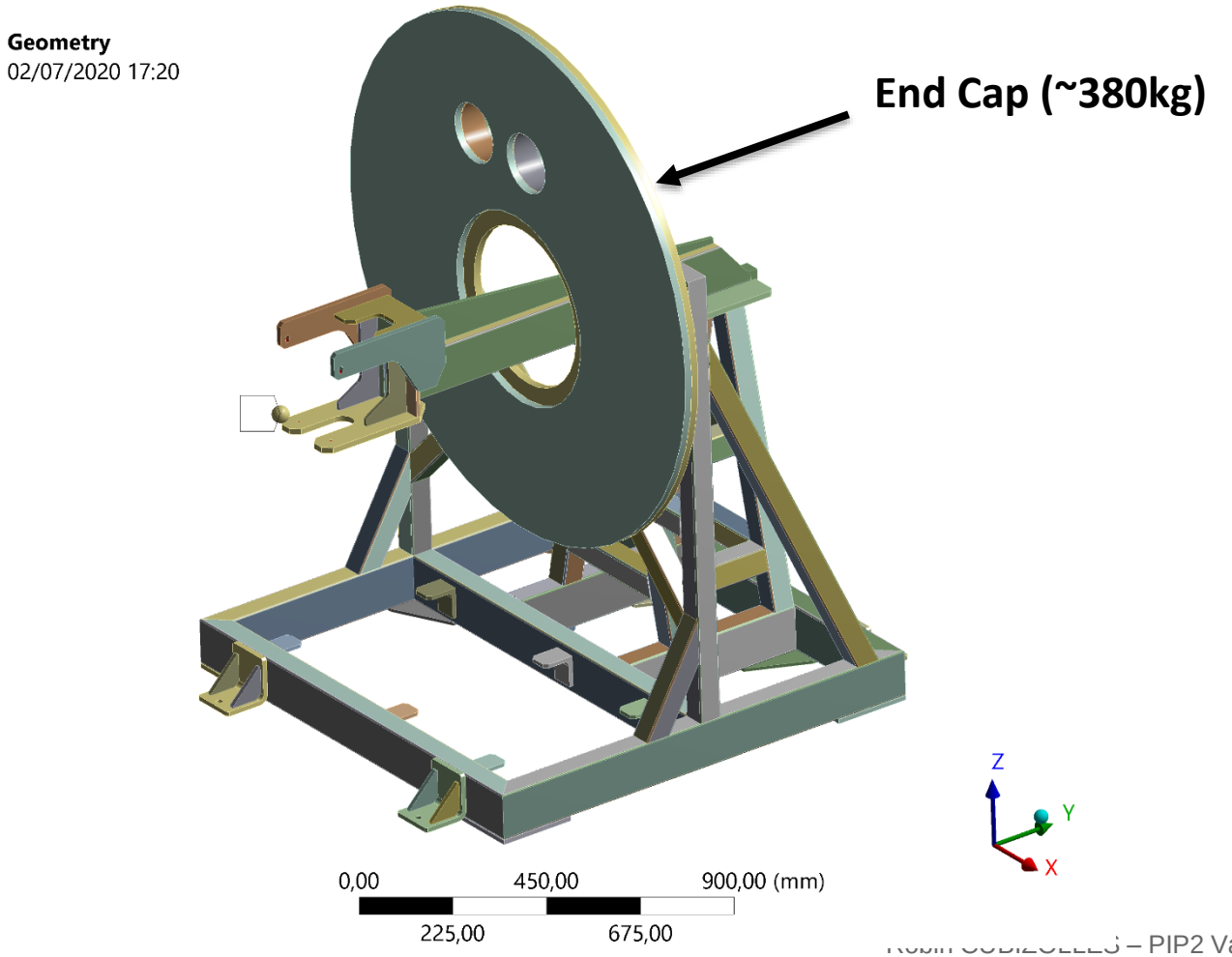
Tooling made of S275 Steel. The end cap is not attached to the tooling and the weight of the transition is supported by the tooling arm.



END CAP TOOLING

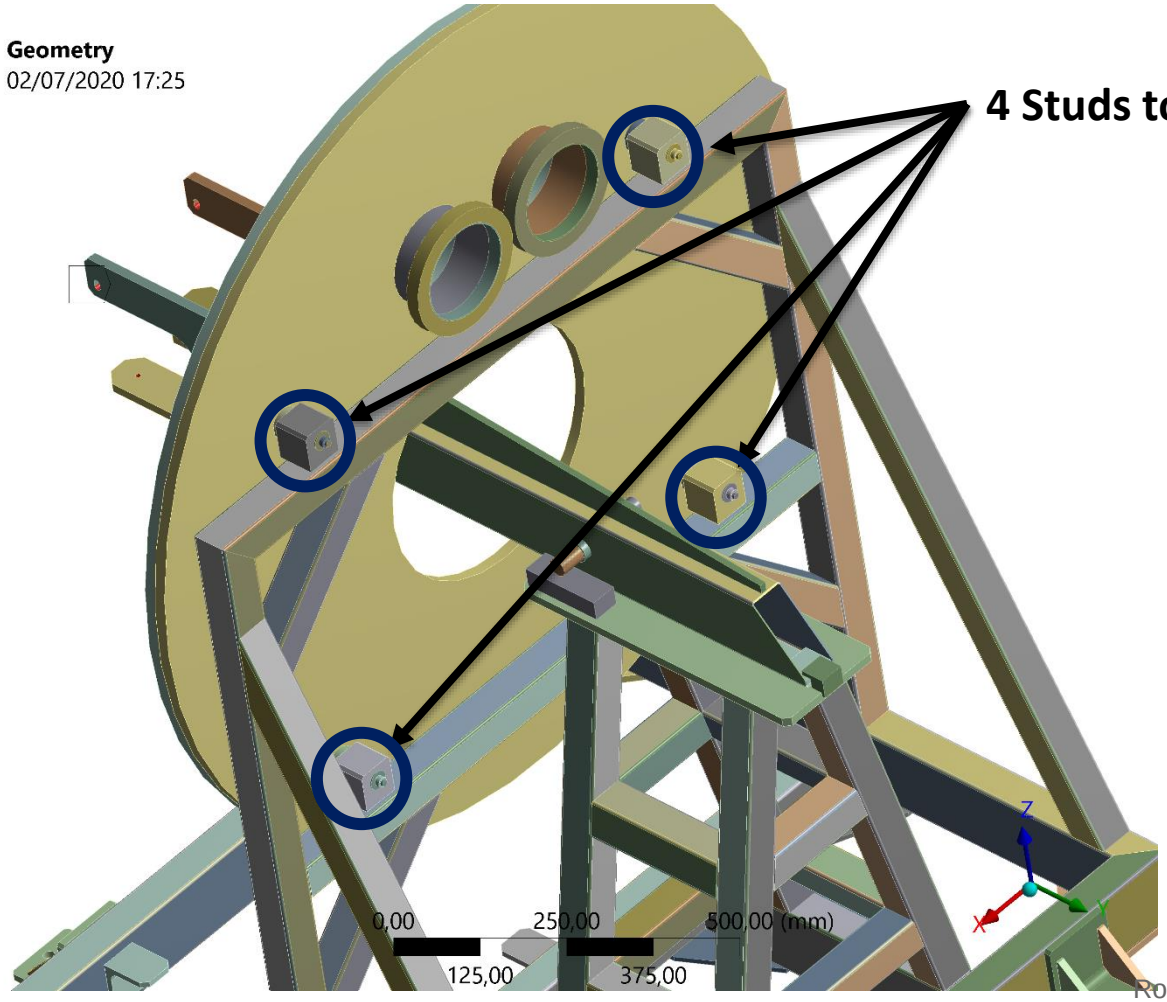
Model with the end cap

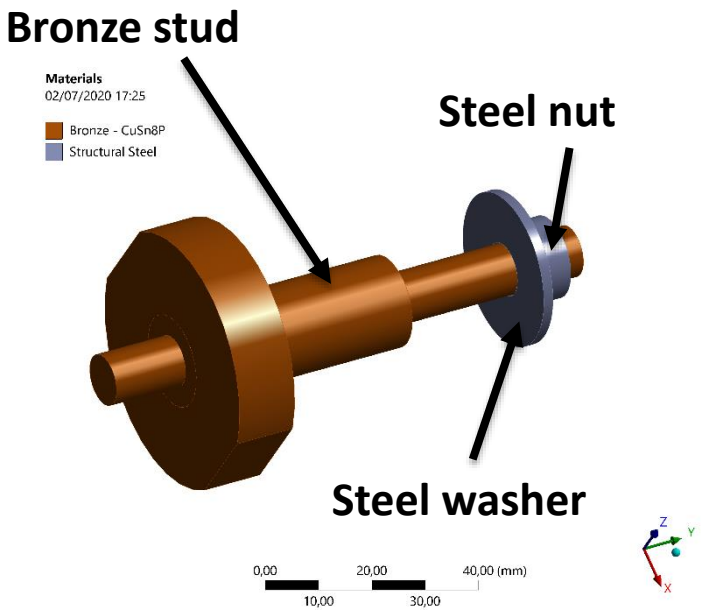
- ❑ Add of the end cap made of 304L.
- ❑ Add of the stud made of CuSn8P bronze.



Model with the end cap

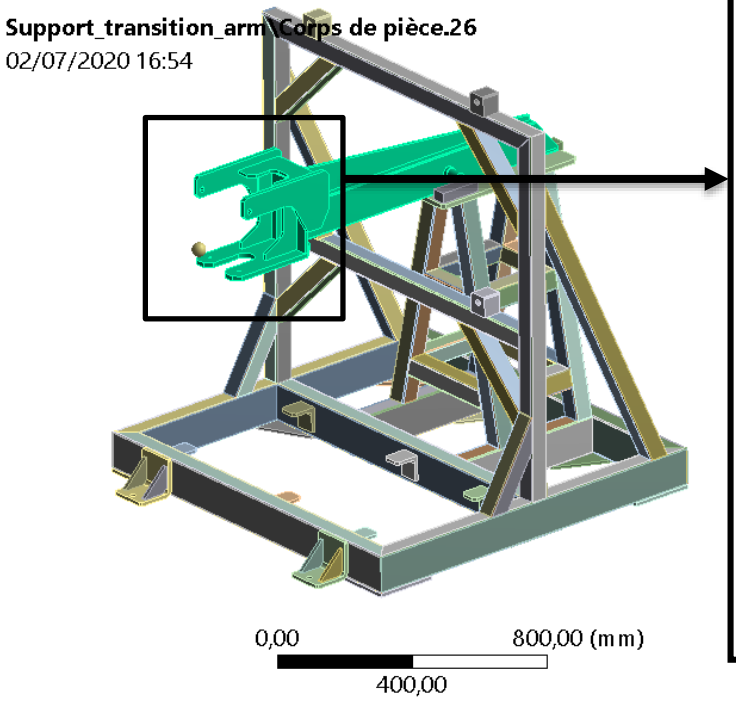
- ❑ Add of the end cap made of 304L.
- ❑ Add of the stud made of CuSn8P bronze.

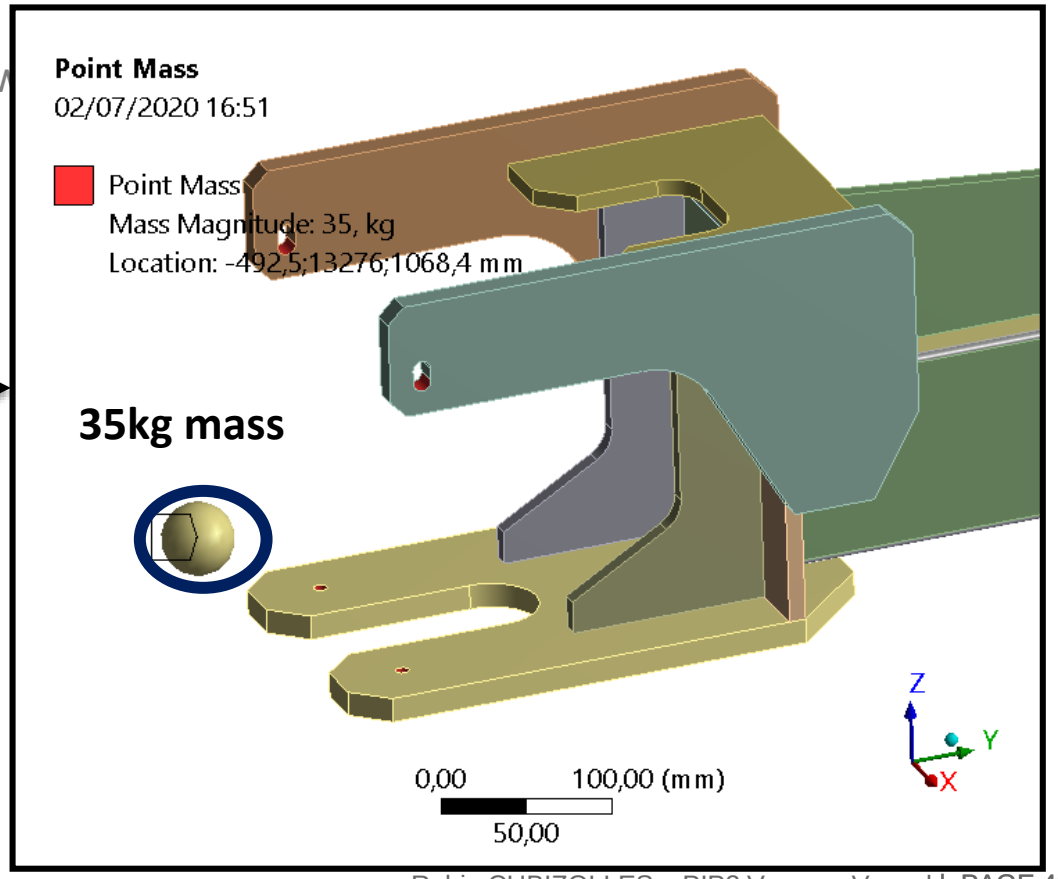




Boundary Conditions

- ❑ Cold-Warm transition mass of 35 kg attached to the “arm” of the tooling.
- ❑ The 4 feet are fixed on the surface where they are screwed.
- ❑ Beam line is under vacuum thus a horizontal force of 285N is applied to the tooling “arm”.
- ❑ Gravity at 1g is set.
- ❑ Revolute joint at the interface betw

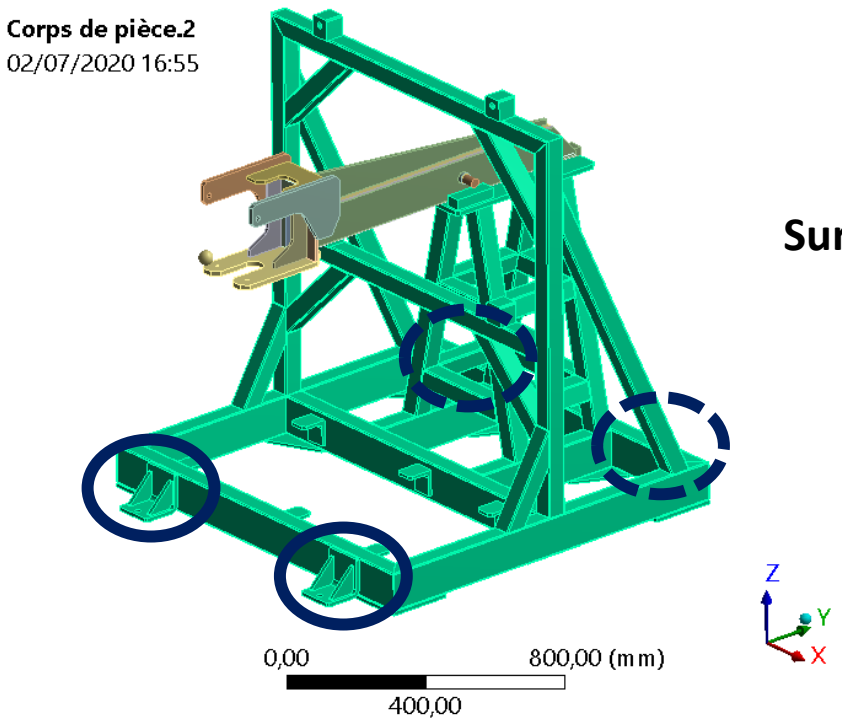


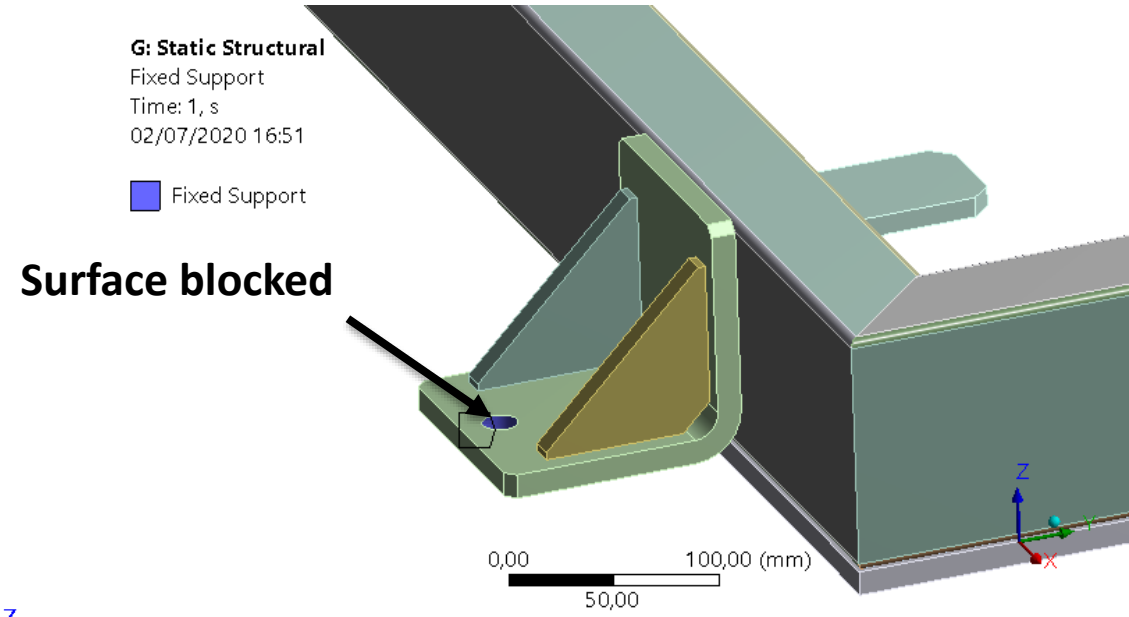


END CAP TOOLING

Boundary Conditions

- ❑ Cold-Warm transition mass of 35 kg attached to the “arm” of the tooling.
- ❑ The 4 feet are fixed on the surface where they are screwed.
- ❑ Beam line is under vacuum thus a horizontal force of 285N is applied to the tooling “arm”.
- ❑ Gravity at 1g is set.
- ❑ Revolute joint at the interface between the arm and the chassis.





END CAP TOOLING

Boundary Conditions

- ❑ Cold-Warm transition mass of 35 kg attached to the “arm” of the tooling.
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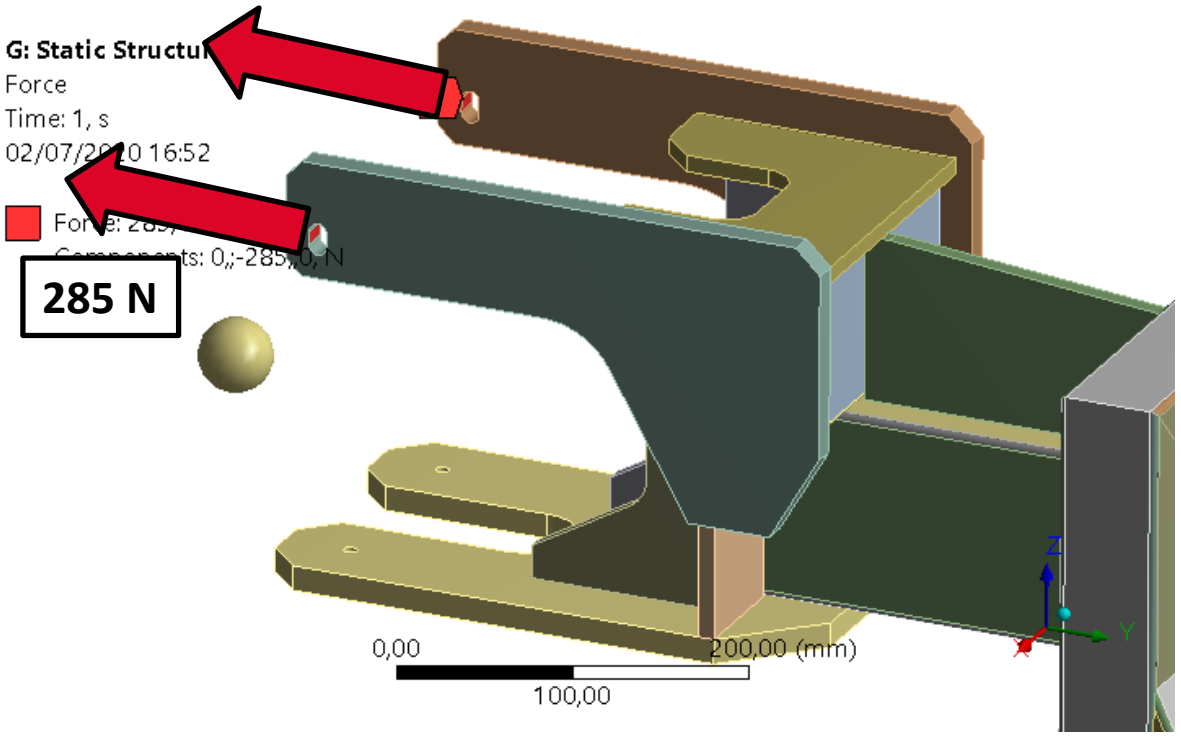

Boundary Conditions

- ❑ Cold-Warm transition mass of 35 kg attached to the “arm” of the tooling.
- ❑ The 4 feet are fixed on the surface where they are screwed.
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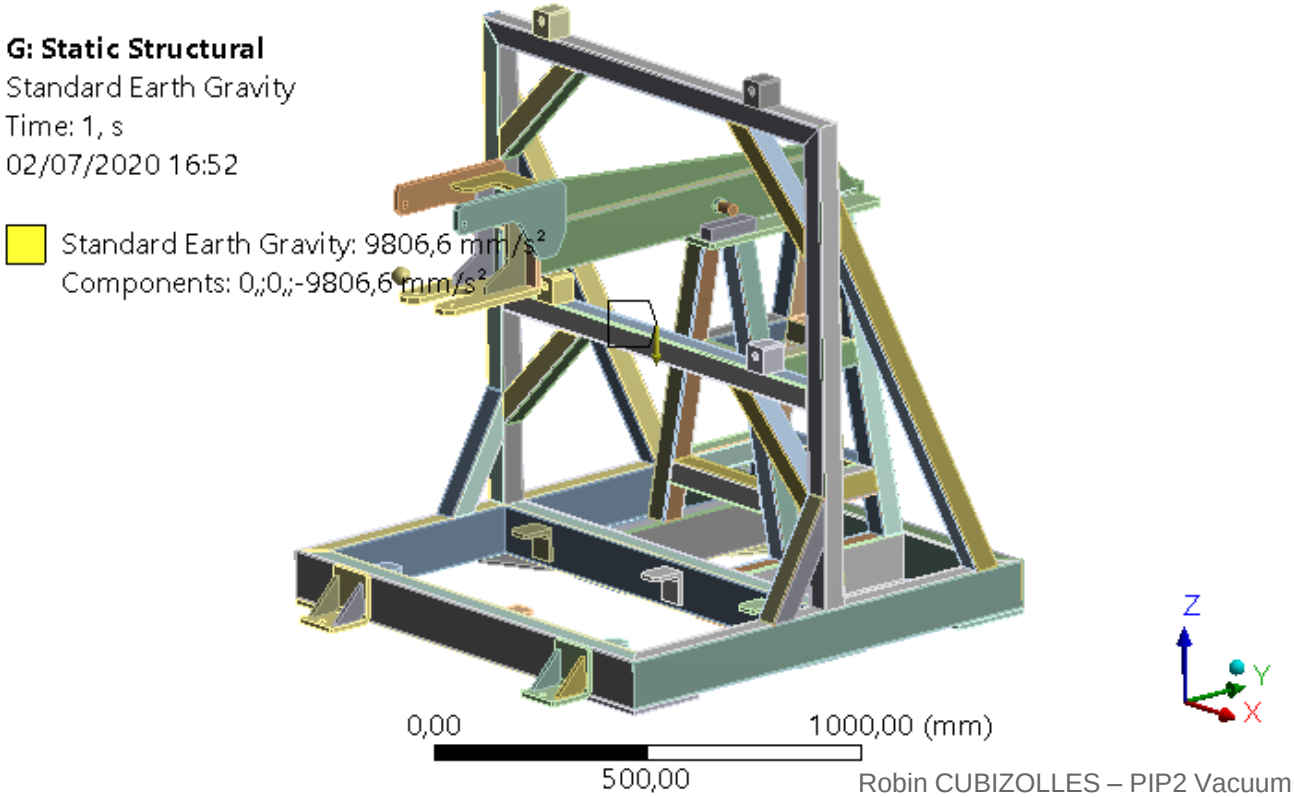

Boundary Conditions

- ❑ Cold-Warm transition mass of 35 kg attached to the “arm” of the tooling.
- ❑ The 4 feet are fixed on the surface where they are screwed.
- ❑ Beam line is under vacuum thus a horizontal force of 285N is applied to the tooling “arm”.
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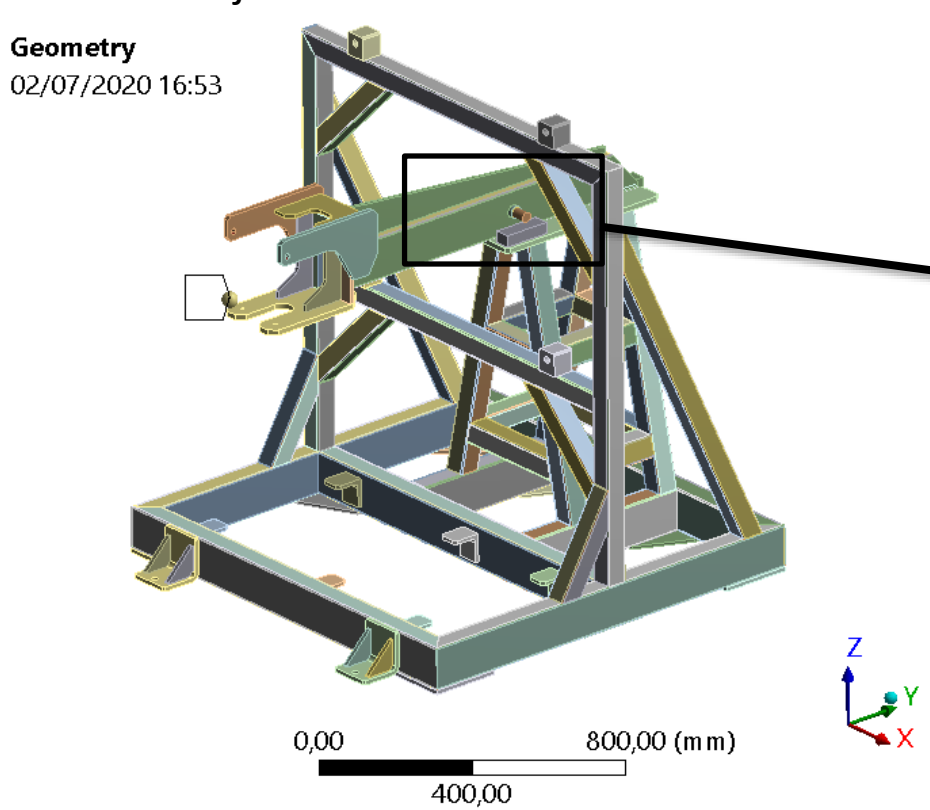
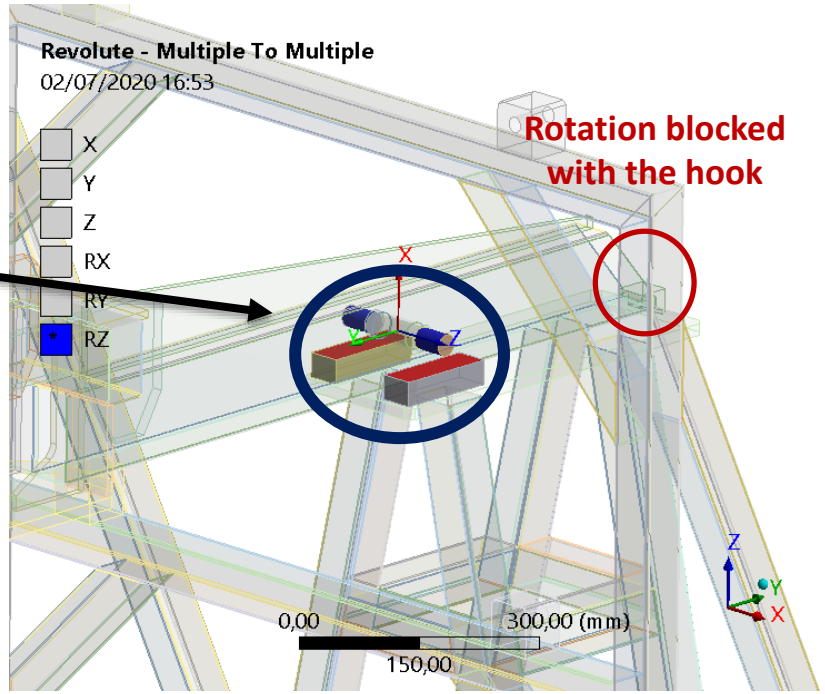
- ❑ Revolute joint at the interface between the arm and the chassis.

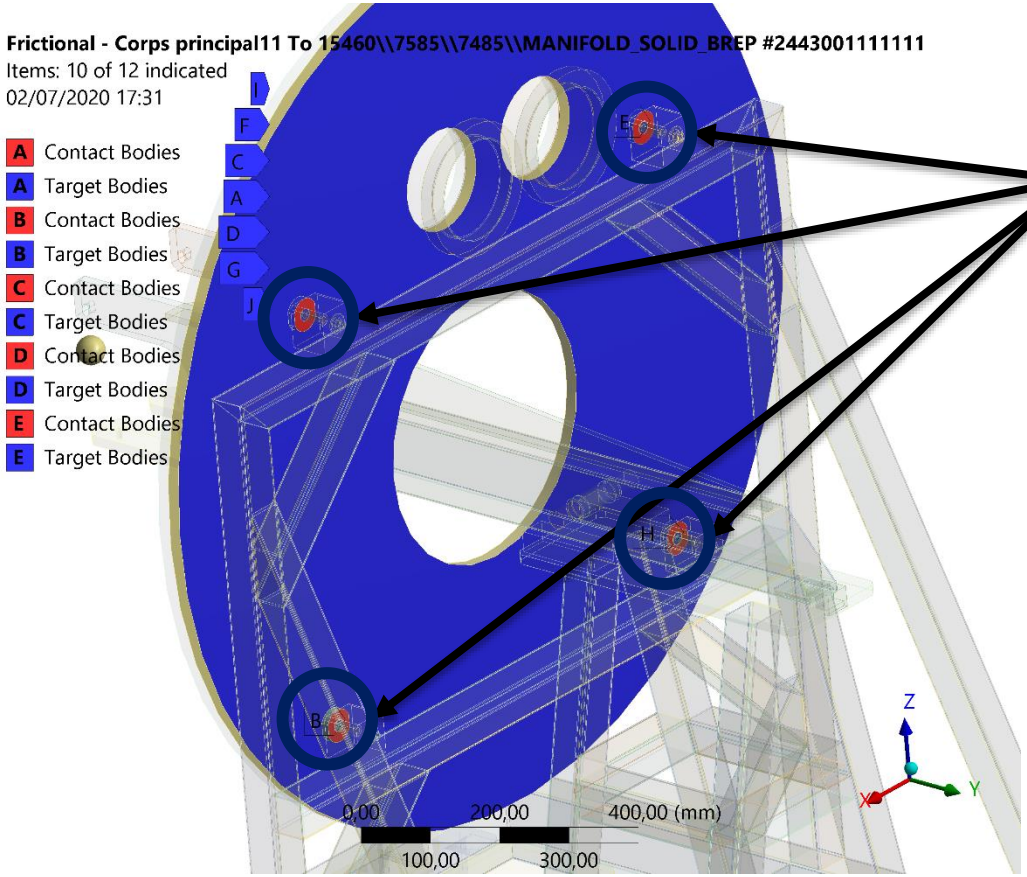




Boundary Conditions with end cap

Compared to the previous simulations the end cap tooling have been added. Thus, the stud are used in order to maintain the end cap by applying a force due to pretension.

Frictional contact with a coefficient of 0,2 is applied between the end cap tooling face and the stud faces.

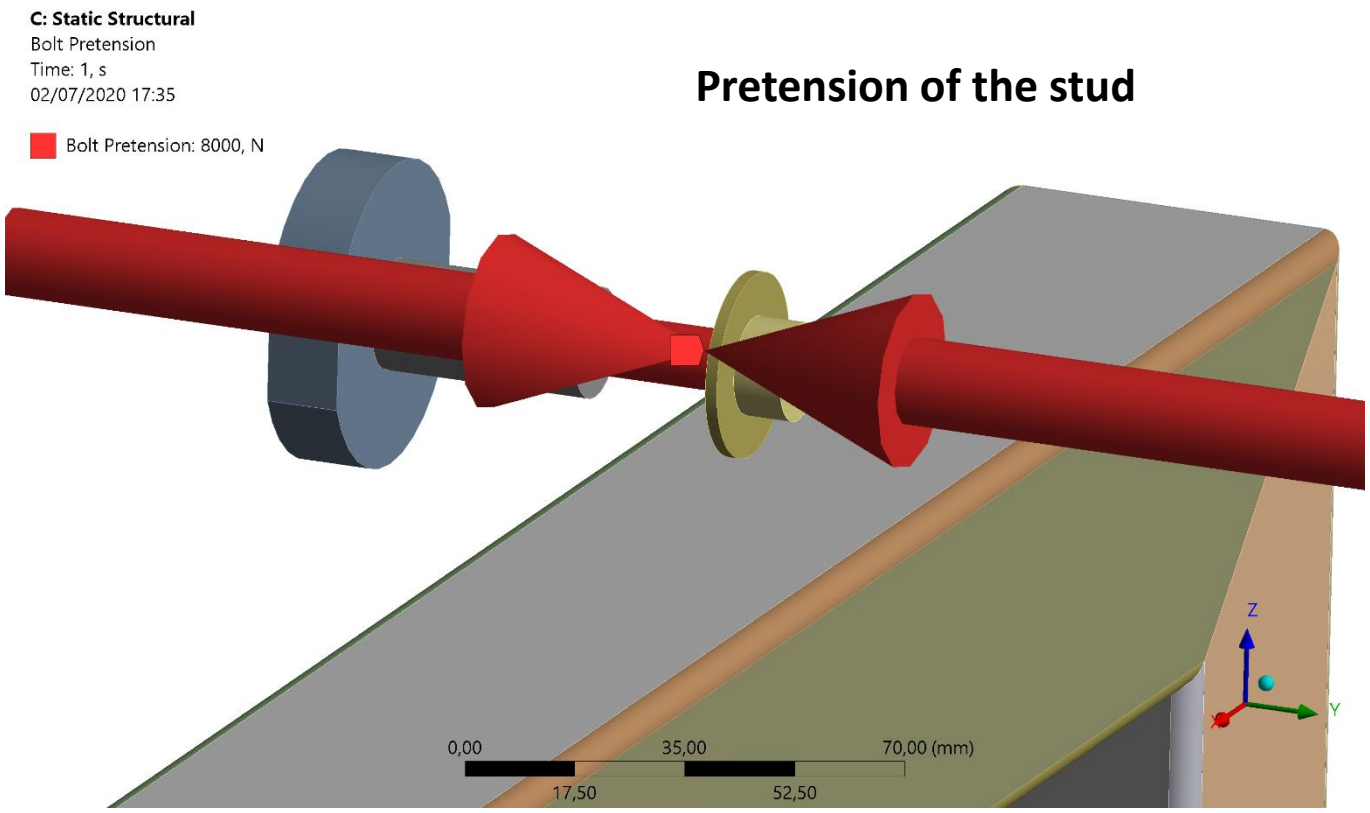


Stud face with friction

Boundary Conditions with end cap

Then, a pretension of 8kN for each stud is applied before applying the gravity in order to maintain the end cap on the tooling.

The pretention of 8kN correspond to a torque of 19-20 N.m.



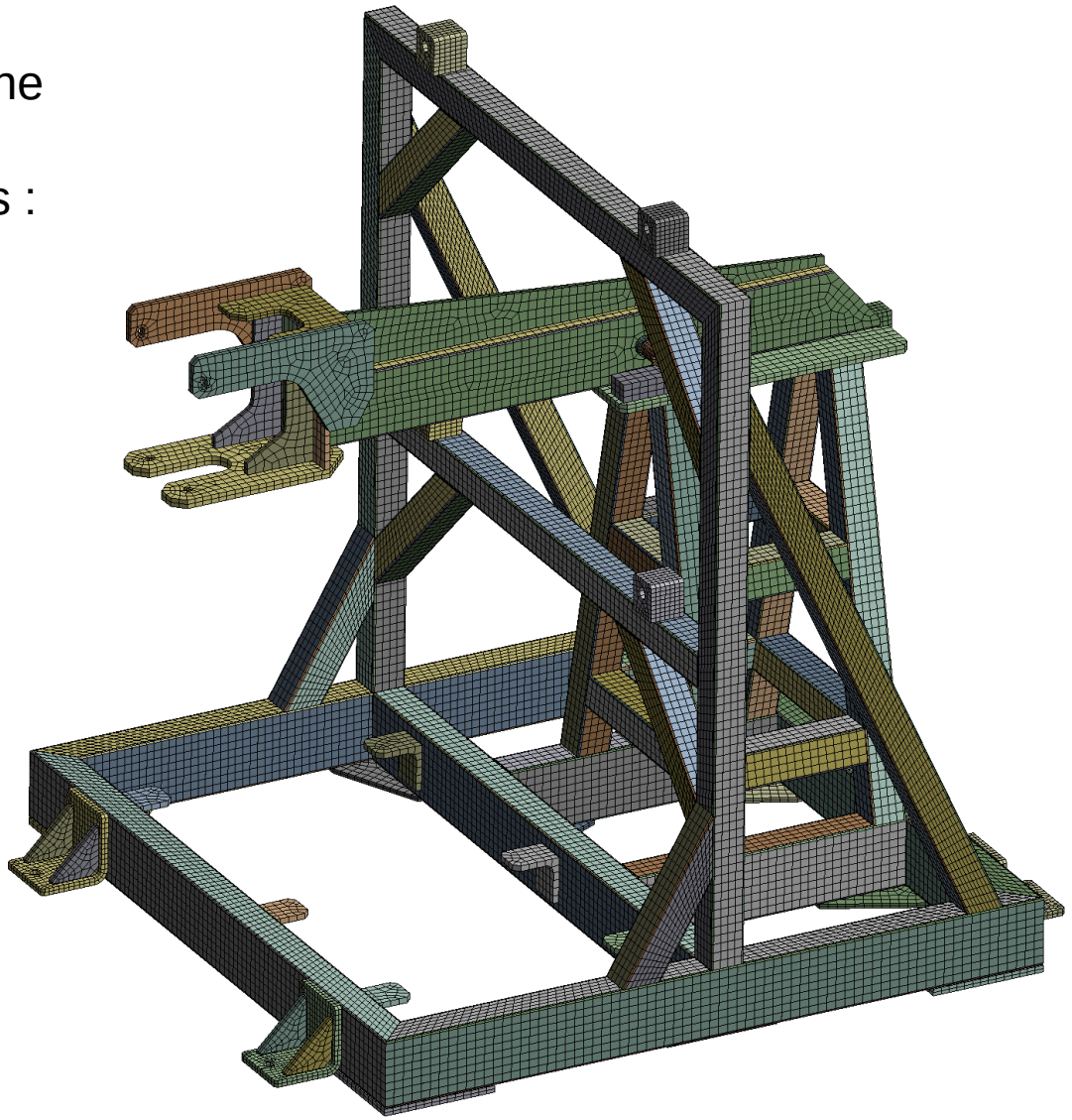
END CAP TOOLING

Mesh

Two elements in the thickness for the tubes.

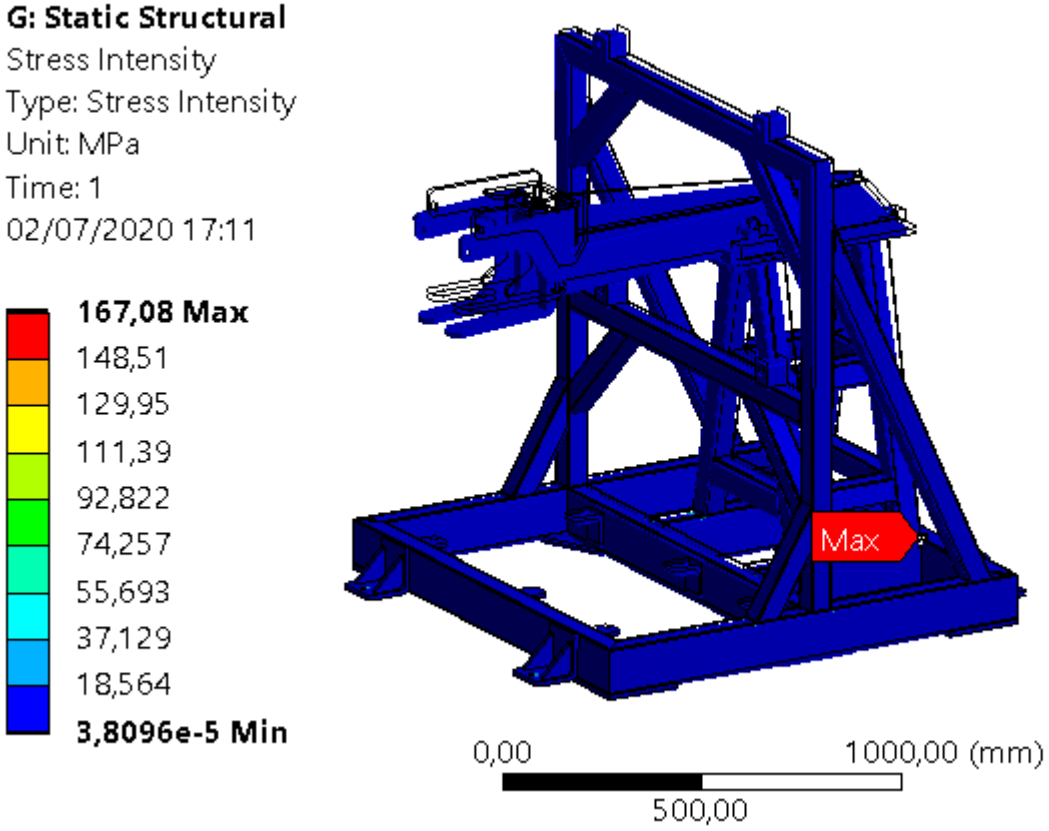
Mainly made of quadratic hexahedrons :

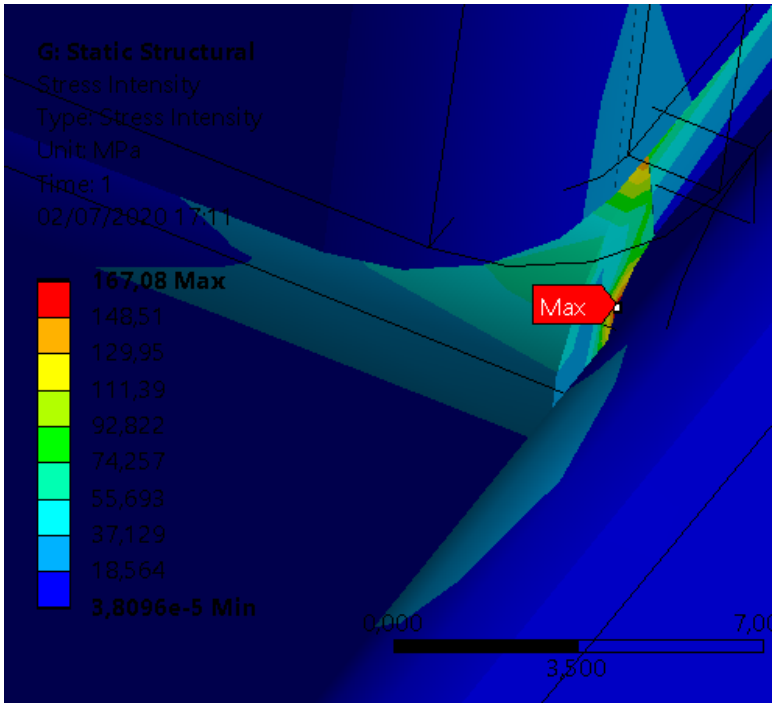
- ❑ 542 015 nodes
- ❑ 95 630 elements
  - 94922 Hexahedrons (Hexa20)
  - 708 Prism (Wed15)



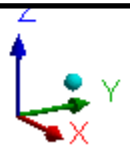
Stress results – Step 3

- Stress intensity : max 167 MPa



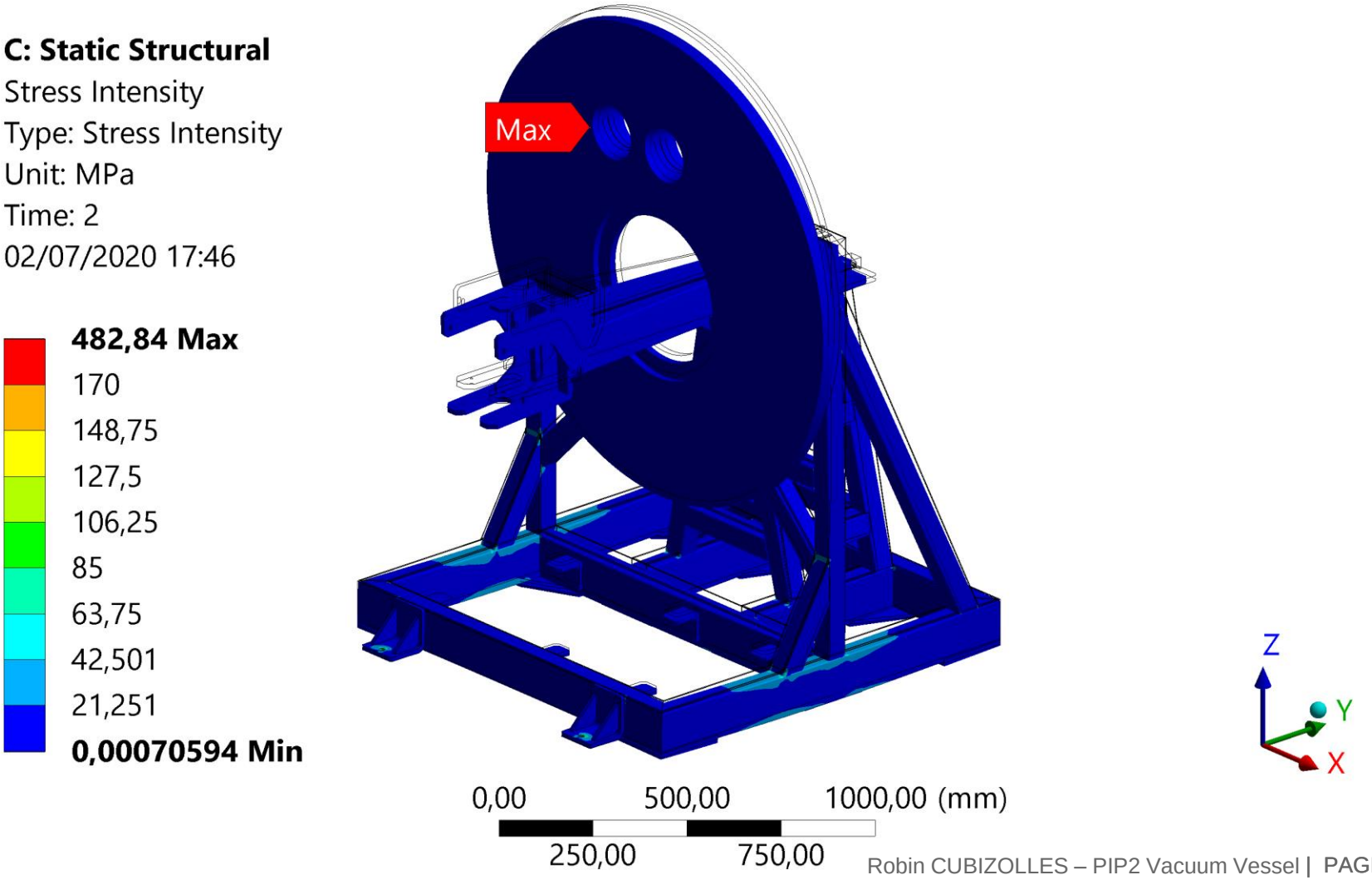


Maximum on a junction between 3 rectangular tubes



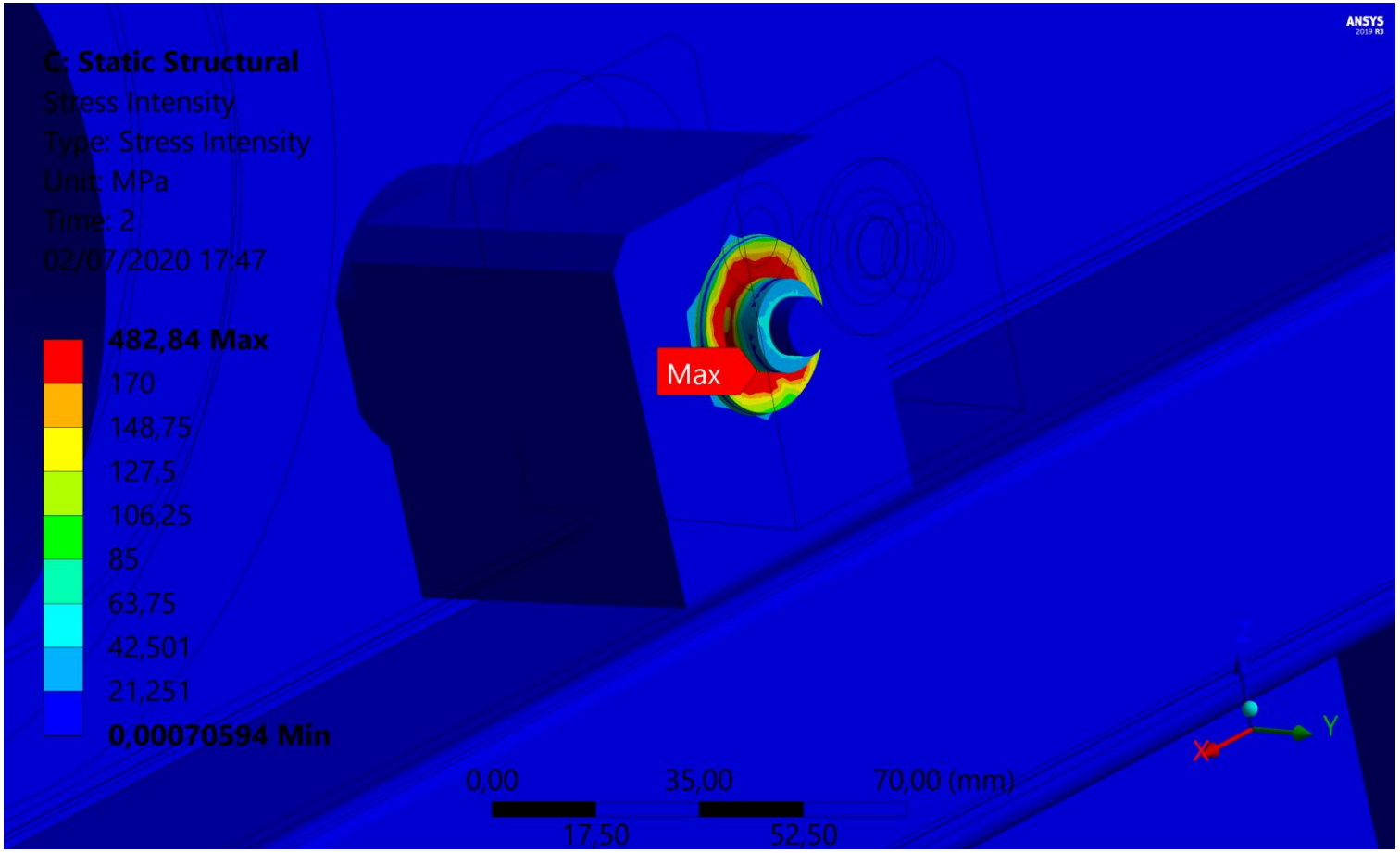
Stress results – Step 2

- Stress intensity : max 483 MPa



Stress results – Step 2

- Stress intensity : max 483 MPa located on the steel washer → **acceptable**



Stress results – Step 2

- Stress intensity on the stud : average 100 MPa (Bronze CuSn8P $R_{p0,2}$=280MPa) → **acceptable**